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ETHNOLOGY OF TUBUAI

BY

ROBERT T. AITKEN

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Robert T. Aitken, Research Associate in Ethnology, was a member of the Austral Islands party of the Bayard Dominick Expedition, 1920-1921 and 1921-1922. Because of illness and difficulties of transportation, the time available for field work was reduced to eight months, which was devoted primarily to investigations on the island of Tubuai.

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Ethnology of Tubuai

By Robert T. Aitken

INTRODUCTION

GEOGRAPHIC SKETCH

The island of Tubuai is part of the Austral Islands, a group which includes Sands (Hull), Rimatara, Raivavae,[1] and Rurutu islands. It lies about 400 miles south of Tahiti, and more than 700 miles east of Rarotonga, the nearest centers of white population. The climate of the island is mild, and the winds, though not definitely seasonal, are prevailingly steady from the east-southeast. But as the island lies near the limit of the southeast trades and thus within the hurricane belt, travel in the summer months is sometimes dangerous. As contrasted with the "low" Tuamotu Islands, Tubuai is "high" but is entirely surrounded by a barrier reef, the outer part of which lies 1 to 3 miles off shore. (See Pl. II.) The reef is usually awash, except for seven islets, four of which are well wooded with coconut palms, hau (*purau*), toa (*Casuarina sp.*), and some undergrowth. The three other islets are sand banks upon which little vegetation is to be seen. On the northwestern side the reef is broken by a wide pass, and elsewhere by smaller ones. Only the pass opposite Mataura affords entrance for vessels other than canoes or ships' boats. (See Pl. I.)

The greatest elevation on the island is Mount Taitaa, 1,300 feet high (399 meters). Looking from a distance north or south, the high portions of Tubuai appear as two separate islands, but closer approach shows them joined by lower land. Approximately half of the island is mountainous, a quarter is swampy, but the beach strip and the lower portions of the valleys afford sufficient land for the relatively small population.

Tubuai is evidently of volcanic origin. All the rock, except that of coral formation, is igneous. There are, however, no lava flows or other evidence of recent volcanic action. No commercially valuable minerals have been found.

Tubuai was discovered by Captain Cook, on August 8, 1777. The *Bounty* mutineers attempted to settle there in 1787, but quarreled with the Tubuai people and after a bloody battle returned to Tahiti. The island was

[1] As the spelling "Raivavae" is that officially used in French Oceania it has been adopted (1930) for Bishop Museum publications. Other spellings (Ravaivai, Raivavai, Raevavai, Raevavae) appear on many maps and in standard reference books published in French, German, and English. Likewise, "Rimatara" (*rima*, five; *tara*, peak) replaces the widely used spelling "Rimitara."—Editor.

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next sighted in 1797 by the missionary ship *Duff;* but learning of the unfortunate experience of the *Bounty* mutineers, the missionaries did not care to land. In 1822 the Tubuai people sent to Tahiti for Christian missionaries, who were promptly supplied, and since that time relatively frequent intercourse has existed between the island and the outside world. In 1842 Tubuai was placed under the protectorate of France, and since 1880 it has been a French possession.

The past and present population of Tubuai is shown in the following table which includes all the information I was able to obtain. The figures for 1821 and 1822 are estimates only; those for 1823 probably are correct within ten per cent, and those for 1849 are not substantiated by records. The figures for the other years are probably correct within two per cent.

DATE	POPULATION	AUTHORITY
1775	Inhabited	Gayangos (24)[1]
1821	900	Montgomery (34)
1822	600	Montgomery (34)
1823	300	Montgomery (34)
1838	Sparsely populated	Du Petit Thouars (19)
1849	180	Lucett (29)
1887	397	Official census
1892	429	Official census
1897	472	Official census
1900	494	Caillot (12)
1917	543	Official census
1921	712	Official census
1922	755	Official census

Commercially the island is of little importance. Its exports are copra, manioc starch, vanilla, coffee, and live stock. Its local trade demands the usual supply of flour, sugar, rice, salt, clothing and dress goods, implements, and miscellaneous small necessities and luxuries. Half a dozen very small stores operated by Chinese, acting either independently or as agents of Tahiti firms, control commerce.

Communication with neighboring islands and with Tahiti is very uncertain. The French Government subsidizes a power schooner with the understanding that regular trips shall be made through the Austral Islands on mail service, but no definite schedules are followed. Trading schooners, sailing craft of 35 to 100 tons register occasionally call and carry mail. Sometimes two schooners come into port in one month, but generally two months or more elapse between boats. The people of the island formerly owned a schooner, which through mismanagement and misfortune has now passed into the hands of a trading concern in Papeete.

[1] Numbers in parentheses refer to the Bibliography, pages 168-170.

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LOCAL RECORDS

Every family of importance in Tubuai, as in other Polynesian islands, preserves a record (*parau tupuna*) by which rights to land may be established. Included in these records are genealogies, accounts of travel and wanderings of ancestors, stories of disputes between individuals and of battles between opposing factions, tales of traditional or mythological happenings, and every sort of information bearing on the land title claims of the family concerned.

The Tubuai records were not available at the time of my visit, and my stay at the neighboring island of Raivavae was too brief to obtain records there. Stokes (43) was more fortunate. His field notes include the whole of an extensive Raivavae record. The following paragraphs are free and somewhat abridged translations of the parts of that record which refer to Tubuai.

Account of Evaarii

Maui espoused Teariivaiheiteahurai (Teariivaihe-i-te-ahurai), daughter of Taareva, the king of the Po. To them were born three sons: Taniau, Evaarii, and Tiarii. Evaarii and Tiarii were twins, Evaarii was born first. Because of a trick of the midwives, Evaarii was thought to be a female, and was thus defrauded of his share in the property when it was divided. For this reason he went to Tubuai, and espoused two Tubuai women, both of whom bore him children. At that time the name of his land was changed to Raivavae, because of the departure of Evaarii for Tubuai.

Evaarii espoused the Tubuai woman Tupuaiehitu (Tupuai-e-hitu) Vahine, in the district of Toerau. Following a dispute with his father-in-law, Evaarii built a boat and started for Raivavae. He changed the name of his district to Toerauetoru (Toerau-e-toru), because of the three children born to him there.

He decided to put to sea through the pass Rautaro, but when he had reached Taahuaia, in the lagoon, he was seen by the girl Hairitemarama Vahine. She induced him, at her father's suggestion, to come ashore. He espoused that girl, and dwelt at Taahuaia. Six children were born to him by that woman, and he therefore changed the name of the settlement to Eononatieva (E-ono-natieva). (See the records of Taahuaia, Tubuai. [It is thought that the country formerly known in Raivavae as Raroata was Tubuai, that Raroata was the older name for Tubuai.])

Account of Narai

Naraitane had four names: Narai Tane, Tetuatapuivaiuru Tane, Huri Tane, Tetinohoroa Tane. Narai Tane espoused Marataurihau Vahine. She bore him three sons and one daughter.

One day he visited his son Tetupu and his daughter-in-law. He led the daughter-in-law to Vaiuru, and when upon the mountain Arahou he assaulted her. He was seen by the people, and because of shame at his evil act, he decided to build a boat and go to Tubuai. His ship entered the lagoon at the pass Hue, and he landed at the village of Nahitiorono. He and his people fought with the people of Nahitiorono, and conquered them. The prize going to them, Narai and his people dwelt there.

Narai Tane espoused Araiatahitiorona Vahine, who bore him four sons. The fourth son was hermaphroditic (*mahu*). Because of this son the name of the village was changed to Mahu. Narai also changed the name of his clan to Naraieha, because

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children were born to him there. He died there at that place. See the records of Mahu in Tubuai.

Account of Teuahau

Teuahau espoused Tuheipuarii, and to them were born three sons and three daughters.

Teuahau prepared to depart for Tubuai. Two boats departed at that time. Teuahau in his boat, and Moeava Tane in his boat. In the boat with Moeava was a Tubuai man, Teahia, who in a canoe had drifted to Raivavae. Teahia and Moeava quarreled out at sea, and in consequence Teahia swam over to the boat of Teuahau. The next morning the boat of Moeava was not to be seen: it proceeded on to Rurutu and nothing is now known of it. Those in the boat of Teuahau sighted Tubuai, and landing on the islet Motiha, they carried the boat ashore at night. The boat and its people remained on the islet, as the people of Tubuai were then heathen, while Teahia swam to the main island and ran to the people in authority, of whom he begged that the people of the boat might be spared. He told them that Raivavae was a good country, where strangers were well treated, as witness the fact that he had been spared. His prayer was granted by those in authority. In the morning the boat and its people were brought ashore. The Tubuaians treated them well, and they dwelt there in peace.

Teuahau espoused ....(?) of Tubuai, and to them were born children. His descendants lived on in Tubuai; one is Tetuatua, wife of Roo-a-Tamatoa Tane. Seek word in Tubuai of Teuahau and of this woman.

These three selections, all from one record, are accounts of three voyages from Raivavae to Tubuai. Each voyage resulted in the infusion of Raivavaen blood, and undoubtedly in the introduction of Raivavaen culture. Numerous minor points of ethnologic interest may be noted, as for example the names of the Tubuai people; the names of passes, and of districts and villages; the distinction made between boats or ships (*pahi*) and canoes (*va'a*); the inference that people cast ashore on Tubuai were maltreated or killed. In studying these records, due allowance must be made for the tendency of the people to exaggerate for the sake of proving title to land. Nevertheless, the records are reasonably dependable, and certainly the careful study of such as may be procured would give a deeper insight into the former culture of the people and the relations between the various islands prior to their discovery by foreigners.

Government records of course are only modern, and consist principally of census lists, court proceedings, landtitle registrations, and various minor writings incidental to the French administration of the island. Most important probably are the census lists, as from them there can be gained some idea of the fluctuation in population, the degree of foreign influence at different dates, and the wanderings to and away from Tubuai of various individuals and families. The oldest of the French documents goes back only to 1880, at which time Tubuai became definitely a French possession, consequently the Government records are relatively unimportant.

The local church records are almost useless, as the historical data is intermingled with attempts at sermon writing by the various church his-

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torians, who were also the preachers. A patient and time consuming study of all the material available might yield a little information of ethnological or historical interest, but I strongly doubt that the effort would be worth while. I attempted to untangle some of this material while in Tubuai, but after a tedious pilgrimage through two old ledgers filled from cover to cover with sermons, exhortations, and testimonials, lightened now and then by the briefest of references to non-secular subjects, I gave up in despair.

The records of the missionaries who visited Tubuai in early days may be of interest, but have relatively little value. It appears that the Protestant missionaries who resided in Tubuai were natives of Tahiti, and naturally their journals or letters are not likely to yield much beyond notes on the progress of the Gospel. The Catholic Church has maintained a mission in Tubuai only in very recent times. The Church of Jesus Christ of Latter Day Saints was established only in 1844. No missionary records of these organizations are at present available other than those now in published form.

Traditions still exist in Tubuai and in the other Austral islands, and much material of ethnological and historical interest is to be gained from their study. My meager collection of Tubuai mythological material (pp. 102-115) yielded some information, and I believe that a considerable mass of similar material still may be obtained.

PUBLISHED RECORDS

In the accounts published by voyagers and missionaries of their visits to Tubuai in early days, are a few notes worthy of attention. I have taken account of these in this paper, but have thought it unnecessary to reproduce the actual passages from the original authors, as most of these books are readily available. Although I have tried to make the Bibliography exhaustive, there are undoubtedly omissions and oversights.

A PERSONAL WORD

The selection of Tubuai as my field of work was largely accidental. In putting into effect the instructions to make an ethnographic survey of the Austral Islands and Rapa, Mr. Stokes and I had agreed to consider the islands as three groups: Rurutu and Rumatara; Tubuai and Raivavae; Rapa. It was further agreed that Mr. Stokes should have the first opportunity to go to either island in either of the first two groups, and that I should go to the other group as soon as the opportunity afforded. Rapa was to be an objective for either or both of us, as its importance was supposed to warrant doubling of forces. It so happened that after Mr. Stokes' departure for Rurutu in December, the next southbound schooner went to Tubuai, and thus my destination was determined. Except for a short stay in Rai-

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vavae and very brief visits to Rurutu and to some of the Society and Tuamotu islands, my entire time was spent in Tubuai. It should here be added, that owing to various delays and to the necessity of returning to Tahiti for treatment and convalescence from an attack of typhoid fever, only about eight months were actually spent in field work.

I cannot express my appreciation of all the courtesies and kindnesses shown me in Tahiti and Tubuai. I must, however, mention some friends who stand out in my memory as having been exceptionally helpful.

In Tahiti, the officials of the Pacific Coconut Products Corporation were more than friendly. Mr. and Mrs. Francis O'Laughlin Killorin, and later Mr. and Mrs. N. P. Selover, took me into their homes in Papeete when illness forced my return from Tubuai. Their generous hospitality greatly hastened my convalescence. Mr. V. L. Wilson was very helpful in financial matters. Through the courtesy of these people in placing at my disposal the resources of their company, I was able to visit Raiatea, Borabora, and several of the Tuamotu islands.

Marau Taaroa Terâ i Farepua, ex-queen of Tahiti, was always graciously ready to help with my studies. Mr. J. Frank Stimson gave me much valuable assistance with the Tahitian language and literature. Monsieur Lucien Sigogne, and Mr. Howard Withey, the American Consul, helped in many ways, notably in elucidating the French law. To Mr. William Crake, who accompanied me on a trip to Rurutu, Tubuai, and Raivavae, I owe my best photographs, many of which he himself made. Rev. Emm. Rougier was throughout a helpful friend, rendering numerous services that only he, through his knowledge of the people and local conditions, could have rendered.

In Tubuai, Mr. Eugene Doom was an invaluable friend; mere thanks are slight return for the unselfish services of Araiaimoiti, my nurse during a siege with typhoid, and of Araiatehere, who relieved me of all household cares during my final stay in Tubuai. I have never worked with so pleasant a people, nor made so many friends as in Tahiti and Tubuai.

To Mr. John F. G. Stokes I am much indebted for the discussion of Tubuai stone implements (pp. 133-167), and for the descriptions of tapa mallets.

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FAUNA

SOURCE

The Tubuaians believe that before the visit of the first foreigner their only animals were the pig, the dog, the rat, and the chicken. The pig, dog, and chicken were domesticated; although some had escaped and had become practically wild.

The pig was described to me as a lean animal, with a rough coat and long ears, comparable with the "razor-back hog" of the southern United States. I was told that until fifty or sixty years ago these pigs were still plentiful, and that a few were running wild as recently as 1890. The dog was described as a small animal of one variety. The rat was described as black, and smaller than the grey rat now common. No skeletal remains of these animals were found, and traps set failed to catch any black rats which are said to exist in isolated places. The chickens, now so plentiful, are ordinary barnyard fowl with no apparent traces of mixture with any primitive stock.

The foreigners brought other varieties of pig, dog, rat, and chicken, which apparently have absorbed or displaced the former varieties. Horses, cattle, sheep, goats, cats, turkeys, ducks, and geese have also been introduced. The modern pig is raised from stock bred locally, with constant infusions of foreign blood from animals brought from Tahiti.

BIRDS

The birds of Tubuai are representatives of eleven species. My record includes all those collected by Seale (39) and by Beck and Quayle of the Whitney South Seas Expedition (52). As no person consulted was able to name any other birds as belonging to this island, it is believed that the list given in Table 1 is exhaustive. It must be understood that the positive identifications apply only to the Tubuai names. For example, the Tuamotu names *akiakipunga* and *kivi* apply to certain petrels, but not necessarily to the same ones known in Tubuai as *upoa.* In Manahiki the Tubuai *oio* is known as *rakie* and the name, *ngoio,* equivalent to *oio* is applied to the black tern. The Tubuai names in Table 1 were supplied by Mr. Eugene Doom and checked by other Tubuai people; the Tuamotu and Rapa names were furnished by Mr. John F. G. Stokes, the Marquesan names by Dr. E. S. Craighill Handy, and the Manahiki names by Dr. Stanley C. Ball. The scientific names were supplied by Ernest H. Quayle.

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TABLE 1. COMPARATIVE LIST OF TUBUAI BIRD NAMES

SPECIES	TUBUAI	HAWAII	TUAMOTUS	MARQUESAS	RAPA	MANAHIKI
Gygis alba	aaia		tara	kota'e	pararaki	kakawai (tara = sooty tern)
Heteroscelus incanus	iivi	ulili	torea			
Phaethon lepturus	mauroa	koa'e kea				rakoa
Porzana (probably P. astra)	moho	moho	moho			kotokoto
Anas superciliosa	mo'ora	koloa			mokora	
Anous stolidus	oio	noio	ngoio			rakie (ngoio= black tern)
Urodynamis taitensis	ooroveo			kuku		
Fregata aquila	otaha	iwa	kotaha			maari
Demigretta sacra	otuu	aukuu		matuu		
Phaethon rubricauda	tava'e	koa'eula	tavake	tavake		tawake
Puffinus or Pterodroma (?) (petrels)	upoa	uau kane	akiakipunga; kivi			

FISHES

The distribution and the variation in names of certain Tubuai fishes are shown in Table 2. Most of the Tubuai names were supplied by Mr. Eugene Doom, and checked repeatedly by others in Tubuai. The Hawaiian names are based on records in Bernice P. Bishop Museum; the Rurutu names were furnished by Mr. J. F. G. Stokes (43). As with other forms of animal life, a native name common to two or more islands cannot be taken as necessarily applying to the same species of fish.

The scientific equivalents of the fish names recorded in Table 2 have been supplied by Mr. Henry Fowler, who points out that in the absence of specimens for study the descriptions by Tubuian informants of most of the forms indicated are inadequate for specific identification. The determinations therefore are little more than suggestions.

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TABLE 2. COMPARATIVE LIST OF TUBUAI FISH NAMES

GENUS AND SPECIES	TUBUAI	HAWAII	RURUTU	DESCRIPTION BY TUBUAI INFORMANT
Germo germo	aahi	ahi	aa'i	albicore
	aavere		aavere	blue back, white belly, 3ft. max.
Mugil	anae		anae	see orie and tehu
	apai			red; 10 in. to 1 ft.
	api		api	black; 6 in. to 8 in.
Trachurops crumenophthalmus	ature	akule	ature	blue, like ahuru
Chanos	avaava			red; shape like toau
Etelis carbunculus	haamea		aamea	red; 6 in. max.; big eyes
Epinephelus querus	hapuu	hapuu	apuu	dark color; max. 2ft.; coarse scales; large mouth
	hoa			like hapuu; 2ft. max.; red
Diodon	huihui			puffs up; short spines
[a] Callydon	i'a tia aau			blue; ordinary shape head; marks on head.
Callydon	i'a tia haumeretue		aumeretue	blue, yellow cheeks
Callydon	i'a tia hauraura			red, 1 ft. long
Callydon	i'a tia hautaaona			blue, like aau, but without marking
Callydon	i'a tia mamaria		mamaria	blue back, white belly, yellow cheeks
Callydon	i'a tia nohe			blue, head shape midway between aau and paiiee
Callydon	i'a tia paee		pa'i	blue; ordinary head
Callydon	i'a tia paiiee			blue; 3 ft. max.; blunt head
Callydon	i'a tia roro		roro	not very black; max. 2ft.
Callydon	i'a tia rotea		rotea	like mamaria, but white. These two fishes come inside the reef, in September and October
Hemiramphus brasiliensis	ihe	iheihe		"nail-fish"; blue; spine projecting forward from lower jaw; swims on surface

[a] The name *i'a tia* is applied to the entire genus of parrot fish (*Callydon*). Eleven species are so called, each in addition being distinguished by an individual or specific name. Published literature mentions only one species of *Callydon* from Tubuai, that collected by Seale (38).

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TABLE 2. COMPARATIVE LIST OF TUBUAI FISH NAMES—CONTINUED

GENUS AND SPECIES	TUBUAI	HAWAII	RURUTU	DESCRIPTION BY TUBUAI INFORMANT
	io		said not to occur	silvery white; 2 ft. to 2½ ft.; round; firm, dry flesh; greatly prized; not the o'io
	maini			6 in. average; like tamuri; white
	maito			like parai, but small; black
Hepatus	manini	manini	manini	white, 4 or 5 black vertical stripes
	moi			variety of nanue (?)
Monotaxis grandioculus	mu	mu		white; round; big mouth; very big eye
Lutianus	nanue nato		nanue	grey; flat; coarse scales. If large, nanue; if small, nato
Synanceija verrucosa	nohu	not represented		poisonous spines on dorsal fin
Albula vulpes	o'io	o'io		3 ft. max.; long mouth; round
Sphyraena	ono		ono	like aavere; teeth not so closely set as in tiatao
Thalassona	orare		orari	round; white and light blue; for some reason associated with the ature
	paaihere		paaere (?)	white; if over 3 ft., called urupiti
	paauare			small; blue-grey; no scales
	papai			6 in.; flat; brown
Platophrys pantherinus	patii	patii		flat horizontally; eyes on top
	rui			like hapuu; 1 ft. max.
Lutianus	taivaiva			2 ft. max.; yellow back, white belly
	tamoe			1 ft.; brown; caught only at night
	tamuri tamuri			like nanue, but white; flat; 1 ft. max.
	tarau		tarau	6 in long; like hapuu
Mulloides auriflamma	tauo		tauo	6 in.; like vete, but yellow
Mugil	tehu			see orie and anae
	iihe			red; 6 in. average

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TABLE 2. COMPARATIVE LIST OF TUBUAI FISH NAMES—CONTINUED

GENUS AND SPECIES	TUBUAI	HAWAII	RURUTU	DESCRIPTION BY TUBUAI INFORMANT
Acanthocybium solandri	tiatao	ono	tiatao	like ono, but with teeth set close
Epinephelus	tonu			large mouth, coarse scales; dark color; similar to hapuu, but larger. Said to be man-eating.
Diodon hystrix	totara			long spines
Acanthurus unicornus	ume	kala	ume	flat; brown; 2 ft. max.; hard skin; spines on tail; projection on forehead
Platophrys	unuunu			drab
Ruvettus pretiosus	uravena	walu	uravena	4 ft. to 6 ft.; lives about two miles out; caught at night with wooden hooks; flesh affects some people as purgative
	va'u	ahi	varu	large, blue, round; (bonito ?)
Mullidae	vete	weke		white; 10 in.; two whiskers hanging straight down from lower part of head, under jaw; (see tauo)
	vevo			white; two blue longitudinal stripes on each side

INSECTS

The insects listed below were collected in Tubuai in January, 1923, by Mr. Eugene Doom. The identifications were made by Mr. Edwin H. Bryan, Jr., who states that all of the insects are of species commonly found about houses at low altitudes and that all in the list are known also from many other Pacific islands. It is interesting to note that the Tubuai names given by Mr. Doom apply to large groups of insects rather than to definite species.

arape: *Graeffea lifuensis* Sharp
huhu: *Lithurgus scabrosus* Smith (=*Lithurgus albofimbriatus* Sichel)
manu hamani meri: *Apis mellifera* Linnaeus
manu hamani repo: *Sceliphron caementarium* Drury
manu patia: *Polistes hebraeus* Fabricius
pepe: *Hypolimnas bolina* Linnaeus
popoti: *Periplaneta americana* Linnaeus
purehua: *Chaerocampa erotus* Cramer, and other moths, not identified
rao and rao anaana: Diptera such as *Volucella obesa* Fabricius, *Musca vicina* Macquart and *Sarcophaga sp.*
vava: *Euconocephalus australis* Bolivar
vivi: *Pantala flavescens* Fabricius and *Agrion sp.*
—— *Rhynchium rubipes* Fabricius

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FLORA

NAMES OF PLANTS

The Tubuai people know the botanical resources of their island to a surprising extent. There are few plants that have not been found useful for some purpose.

As a part of my ethnographic work, the native names of plants were recorded. For convenience of reference the names thus obtained are combined with those from printed sources to form the list of plant names given below. In this list the scientific identifications are to be considered tentative. The technical names inclosed in parentheses are copied directly from Butteaud (10) and therefore reproduce inaccuracies which may occur in the original. Furthermore, I cannot be sure that a plant known in Tahiti by a certain name has the same name in Tubuai and the identifications of Butteaud made for Tahiti may not be applicable in Tubuai. The identifications indicated without mark were made in the field by me on the basis of Butteaud and of Hillebrand (26) and cannot be rated as unquestionably accurate. The identifications indicated by an asterisk (*) are by Dr. Forest B. H. Brown, who found my meager collections inadequate for further specific identification. Dr. Brown calls attention to the fact that *haehaa* (*Tachiadenus sp.*) has been previously reported only from Madagascar, where its high medicinal value is recognized, and suggests that the plant may have been used by the Polynesians during their early wanderings.

LIST OF TUBUAI PLANTS

aeho (see *to*): Erianthus floridulus
ahia: (Jambosa malaccensis)
ahia popaa: (Jambosa vulgaris)
aito (see *toa*): Casuarina equisitifolia
amia: (Siegesbeckia orientalis)
anani: Citris aurantium
anuhe: (Gleichenia dichotoma)
aoa (see *oraa*): Ficus prolixa
apara: Malus var. (?)
ape: Alocasia macrorrhiza
aretu (see *nonoha*): (Paspalum scrobiculatum)
aroro: (Cucurbita multiflora)
atae: (Erythrina indica)
ati (see *tamanu*): Calophyllum inophyllum
aturi: (Portulaca oleracea)
autaraa: (Terminalia glabra)
aute (or aurii): Broussonetia papyrifera
avaava: Nicotiana tabacum
avaava irai: (Piper latifolium)
ava turatura: (Piper methysticum)
avaro (see *upa*): (Premna tahitensis)
avota: Persea gratissima
fara: Pandanus sp.
faurau maire: (Hibiscus trilobatus)
fautia: (Abelmoschus moschatus)
fei: Musa (fei)
haari: Cocos nucifera
haehaa: Tachiadenus sp.
hoi: Dioscorea sp.
hora: (Tephrosia piscatoria)
horahora: (Lepidium piscidium)
hue: gourd
hue hue: (Karivia samoensis)
hutu: Barringtonia speciosa
iita: Carica papaya
iriaeo: (Urtica interrupta)
mafatu anae: (Bolbophyllum longiflorum)
mahame: (Glochidion ramiflorum)
maiore (see *uru*): Artocarpus incisa
mama: (Mammea americana)
maniota: Manihot utilissima
mape: Inocarpus edulis
mapua: Compositae (sp.?)*
mapua no'ano'a: (Adenosma fragrans)
mara: (Nauclea rotundifolia)
mata pio: An unidentified fern

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mati: Ficus sp.
matia (matie) tatahi: Paspalum sp. (?)*
maupo: Dianella ensifolia?
mauu (see *mou*): Cyperus pennatus*
mave: two unidentified plants
meia: Musa var.
mereni popaa: Cucumis melo
mereni tahiti: Cucurbita citrullus
metua puaa: Polypodium sp.*
miri: (Ocimum gratissimum)
miro: (Thespesia populnea)
moemoe: (Phyllanthus virgatus)
mori: (Crossostyles biflora)
mou (see *mauu*): Cyperus pennatus*
mou upoonui: (Kyllingia monocephala)
nahe: (Angiopteris evecta)
nanamu: (Panicum sanguinale)
nave: (Brassica nupus)
niho roaiti (or *niu*): (Leucas decemdentata)
nono: Morinda citrifolia
nonoha (see *aretu*): (Paspalum scrobiculatum)
oaha: fern
ofai: (Agati tomentosa)
ofe or ohe: Bambusa sp.
ofe ofe: Panicum sp.*
opaero: (Typha angustifolia)
oporo: Solanum (anthropophagorum)
oporovainui: (Gyrocarpus asiaticus)
Opuhi: (Amomum cevuga)
oraa (see *aoa*): Ficus prolixa
otime: (Mentha peperita)
ouru: (Suriana maritima)
paaura: (Dioscorea sp.
paeore: Pandanus inermis*
paifee: variety of breadfruit
paihi: Oxalis sp.*
painapo: pineapple
parahirahi: (Pentacarya heliotropoides)
patoa: (Cardamine sp.*
pia: Tacca pinnatifida
pia ruatahi: (Pogonia nervilla)
piahoto: (Achrosticum aureum)
pilipitioo: (Abrus precatorius)
pine: (Xylosma suaveolens)
pipi: Phaseolus vulgaris
pipi atai (see *rea moeruru*): Zingiber zerumbet
pipi rarahi: (Vicia faba)
pipi nanai: lentil
pipiri: several introduced grasses characterized by awns, hence the name, meaning prickly
pirita: Dioscorea sp.
pofatuaoao: (Sophora tomentosa)
pohue: two plants, both Convolvulaceae
pohue miti: (Ipomaea pes-caprae)
pohe haavare: Mimosa pudica
pota tihopu: cabbage
pota hinu roroa: chicory
pua: unidentified
puarata: (Melaleuca aestuosa) Metrosideros[?]
puatea: Pisonia sp.
puaveoveo: (Crataeva religiosa)
purau: Hibiscus tiliaceus
rati: radish
rea: Curcuma longa
rea moeruru (see *pipiatai*): Zingiber zerumbet*
remuna: Punica granatum
reva: (Cerbera forsteri)
rima rima tafai: (Lycopodium comum)
rimu pape: water-cress
roti: rose
tafano: (Guettarda speciosa)
tafifi: (Jasminum didymum)
taatahiara: (Dichrocephala latifolia)
tainoa: (Cassytha filiformis)
tamanu (see *ati*): Calophyllum inophyllum
tamarine: Tamarindus indica
tamore: (Polygonum imberbe)
tamore mou'a: (Lepinia australis)
tapotapo: Anona squamosa
tapotapo popaa: Anona muricata
taporo: Citrus limonum var.
taraire: (Terminalia glabra)
taritari: Daucus sp.
taro: Colocasia antiquorum var.
tarona: Nerium oleander
taroti: carrot
tatara moa: (Guilandina bonducella)
teve: (Dracontium polyphyllum)
ti: Cordyline sp.
tiairi: (see *tuitui*): Aleurites triloba
tia papa: (Peperomia rhomboidea)
tiapito anefenua: (Ophioglossum sp.)
tiare tahiti: Gardenia tahitensis
tiatia mona: fern
tipanie: (Plumieria elegans)
tira: (Melia sempervirens)
toa (see *aito*): Casuarina equisitifolia
taofe: Coffea arabica
to (see *aeho*): Erianthus floridulus
to hinu: (Tournefortia argentea)
to maohi: sugar cane
tomati: tomato
torea: (Chiococca barbata)
toroura: (Cyathula prostata)
totoma: cucumber
tou: Cordia sp.
tuitui (see *tiairi*): Aleurites triloba
tupere: (Physalis pubescens)
tupu: (Epidendrum resupinatum)
tutae puaa: (Mucuna gigantea)
tute: Ficus sp.
tutu: (Colubrina asiatica)
tutui foraoa: (Canavalia obtusifolia)
tuvava: guava
tuvava taina: Chinese guava

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tuvava tinito: Chinese guava
uhi: Dioscorea sp.
uhi parai: Dioscorea sp.
upa (see *avaro*): Premna tahitensis)
upaupa tumuore: (Dendrophtoe forsterianus)
upoetii: (Amarantus gangeticus)
uru (see *maiore*): Artocarpus incisa
vaianu: (Adenostemma viscosum)
vairoa: (Boehmeria interrupta)
vanira: vanilla
vavai: two or three plants, unidentified
vi: Spondias dulcis
vi popaa: Mangifera indica
vine: (Vitis vinifera)

AGRICULTURAL PLANTS

Taro

The cultivation of taro in Tubuai is similar to its cultivation elsewhere in Polynesia. Low lands, readily flooded and drained, are at present used for the patches, but in most of the valleys terraced fields indicate former cultivation even well up in the mountains. Hardly 10 per cent of the land suitable for taro is now utilized.

After the location of a new taro patch is decided upon and freed of weeds and undergrowth, the soil is spaded to a depth of 8 or 10 inches with modern spades and shovels, which long ago replaced digging sticks. The preparation of the patch depends somewhat upon the variety to be planted. For varieties that need swampy land the patch is flooded, either before or after spading, until the soil is thoroughly saturated. The patches are so made that the water does not stagnate; most of them are terraced, so that the water flows from the upper patches down through the lower ones, and finally on out. Certain varieties of taro thrive best in land that is irrigated instead of flooded and without flooding or irrigation a few varieties will grow on land newly cleared after lying fallow for several years. But after one crop has been produced, the patch must be irrigated or flooded before replanting. Taro planted on drained or dry land is protected by a mulch of dry coconut leaves, which, if properly laid, needs no renewal until the crop has been gathered and new plants set out. Weeds in dry land taro patches require little attention. In irrigated patches much weeding is necessary and the regulation of water supply and drainage requires care.

Taro is grown from the tops of mature plants. In planting, the top is thrust into the soft soil in such manner that the corm tip is a few inches below the surface, and the petioles of the old leaves, together with such immature leaves as may have escaped the knife, project above ground. The corm strikes root very quickly, and from it the plant is soon regenerated. In gathering taro, the plants are pulled up, tied in bundles, and after most of the leaves are cut away, the bundles are carried home, where the corms are cut off for cooking. The bundles of tops, each consisting of the corm tip with the petioles of the leaves attached, are set aside for replanting. The

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corms are sometimes cut off at the taro patch, and the tops either replanted at once, or set aside for future use.

The Tubuai people recognize 16 varieties of taro. For the 14 given in the following list I have verified the names by descriptions and by observations. I did not see the *apo* or the *apuru* actually growing.

Mapuna. Most common variety; grows best in swampy or freely irrigated land, but newly cleared, fairly moist land will produce one crop; corm the size of an average Irish potato; gray inside after cooking.

Oa. Grows only in swampy soil; red petiole; corm similar to that of the *mapuna*.

Ura nui. Grows only in swampy soil; similar to *oa* except that the corm is red beneath the black outside.

Mata mata. Grows only in swampy soil; red, like *ura nui* and *oa*, except that the corm has many "eyes" beneath the skin which disappear after cooking.

Manaura. Grown only in swampy soil; brown petiole, corm ordinary color and texture; said to have been the only taro known in Tubuai in the old days.

Apuahui. Almost identical with *manaura*, but the Tubuai people make a distinction based on the shape of the leaf.

Tutu. Grown only in wet ground; the upper side of the leaf has a red spot about the size of a ten-cent piece; corm white after cooking.

Orui. Grown only in wet ground; black or very dark petiole.

Pehu. Grown only in wet ground; petiole green with longitudinal white or light lines.

Veo, or taro rearea. Grown usually on swampy land, but also on dry land; corm yellow or copper colored.

Apo. Grown only on swampy land; corm yellow like that of *veo*; petiole a darker color.

Apura. Grows without planting on dry land along stream banks; not used for food except in times of want, as it requires long cooking in the umu. Most frequently used in making *popoi*.

Taro hamoa. Grown on wet land, also on dry land naturally moist or occasionally irrigated; petiole black, very long and stout; leaf exceptionally large; corm very large, weighing as much as 12 pounds. Said to have been introduced from Samoa by way of Tahiti.

Taro tahiti. Grown on very wet land; two varieties with same name, both supposed to have come from Tahiti. One variety has a reddish, the other light colored petiole.

A plant called *ape* is recognized by the natives as not a taro, but in a general way similar. The corm attains immense size; some are several feet in length and 10 inches to a foot in diameter. The leaf is very tall and erect, not drooping like a taro leaf. The *ape* is seldom used as a food, as it calls for special care in preparation. The corm is left in the umu for several days, until quite soft, then crushed, mixed with grated coconut, again cooked in the umu, and after several hours cooking it is mixed with ordinary taro paste. The final product, known as *popoi tioo*, is considered excellent.

Coconuts

CULTIVATION

Sandy soil, near salt water, is the land favored for coconuts. In preparation for planting little is done to the ground besides clearing. The nuts are sprouted in some sheltered place, then planted, in rows, about 15 feet apart each way. For a few years care must be taken lest cattle or horses

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destroy the young trees, or weeds and undergrowth smother them. It is customary to plant some sort of garden truck between rows during this period so that the produce will pay for the care of the land. After they are a few years old it is believed that the coconuts require all the nourishment in the soil, and the growing of garden truck is discontinued. From that time on only a little attention is paid to the groves. Heavy undergrowth is kept down, but weeds are generally allowed to flourish. Few people in Tubuai realize that proper cultivation of a coconut grove will be repaid by increased yield of nuts. This lack of attention, together with the use of many nuts for food, and the sacrifice of enormous numbers to the rats, accounts for the fact that relatively little copra is produced.

Most of the copra exported from Tubuai is made by the Chinese, who operate small stores and acquire a considerable part of the coconut crop in exchange for their goods.

COCONUT OIL

Coconut oil (*monoi*) is in great demand for hair dressing and for rubbing on the body. It is considered inedible. It is still prepared in the primitive manner, by combining coconut oil with one or another of several flowers and herbs, or with some strongly aromatic substance such as vanilla, pineapple skin, or sandalwood. The plants used to provide the perfume include *tiare tahiti, tiare taina, tiare pa, tiare mato'i, tiare pua, miri, otime, taritari, maire, hinano, puarata, painapo, porohiti, iahi, amia, avaro, vanira.*

I watched Taitaitematauira, my sixty-year old adopted grandmother in Mataura, prepare *monoi*. She first had the children grate a large number of dry coconuts, being careful that none of the dark skin of the nut or any foreign matter should get into the grated meat. In the meantime she picked over an immense number of *tiare tahiti* discarding everything but the actual blossoms. These she mixed with the grated coconut meat, filling a large trough-shaped wooden bowl with the mass. The trough was placed in the sun near her house, protected during the heat of the day by a rough coconut leaf mat. Occasionally during this time she stirred the mixture with her hands, and on the second day began dipping out the oil. As the oil exuded, it was bottled and after several days the remaining matter was squeezed until no more oil could be expelled. This last oil was kept separate from the rest, as it was considered of inferior quality. A few bottles, including the inferior product, were sold to the Chinese trader, more were given to relatives and friends, the remaining few were stored away for home use.

The oil may be used as soon as prepared, or may be kept almost indefinitely. If desired, additional perfuming material may be added to the

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bottled product. Grated sandalwood was added to the *monoi* in one of the bottles given me, and imparted to the oil an excellent perfume.

INDUSTRIAL USES OF THE COCONUT

For the native, almost every part of the coconut tree has its use. The roots are used in certain kinds of basketry; the trunk, roughly squared, is the sill or plate upon which many a house wall or roof is erected; the outer skin or bark makes excellent charcoal; the fibrous material at the base of the petioles is a ready-made strainer; the spathe, bound in bundles with the dry leaves and with other inflammable material, makes torches to aid the spearing of fish at night; the rachis and petiole provide long, stiff fibers on which to string candle-nuts and for various other purposes; the green leaf is woven into thatching material, baskets, mats, and into *rauere,* a long drag-net used in community fishing; the dry leaf is used as mulch for taro patches; the husk of the green fruit provides an astringent juice used medicinally; the fibers from the husk of the ripe fruit make the very best sennit; the hard shell of the ripe nut needs only cleaning for use as a bottle and cut in half makes ideal cups and bowls; the meat, grated or otherwise, is highly prized as food, and needs only sun drying to be transformed into copra; the water is considered the best of drinks. Coconut oil is used in cooking, in medicines, as lubricants, and for burning in lamps.

NOMENCLATURE

A botanist would find many varieties of coconut growing in Tubuai. The natives recognize differences but have no distinguishing names for the several varieties. They have, however, a full set of names for the various parts of the tree and for the fruit in its several stages of development, as well as for the numerous products made from various parts of the plant. Following is a list of some of the more commonly used names.

Haari. Coconut in general, applied to the tree, fruit, and nut.

Rautupu. The first sprout or leaf to appear when a germinated nut is planted.

Niau. Coconut leaf, the leaf woven for thatching and the dry leaf used for mulch on taro patches; sometimes used as a general term for the coconut tree.

Fafa. Petiole and rachis of the coconut leaf.

Fa niau. Base of the petiole.

Atiu (or **potiu**). Young coconut fruit just formed.

Niaa. Green coconut, in which the meat has not begun to form. The word *ouo* is also understood in this sense, but is not in use.

Pape haari. Green coconut, at the stage when the water is best for drinking.

Opaa. Mature coconut.

Uto. Mature nut, when sprouted.

Apu (or **maroapu**). Empty shell or half shell of coconut.

O. Stripped of the husk, as a coconut.

Aano. Coconut, stripped of its husk and cleansed, used as a water bottle.

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Aa. The fibrous material at base of the petiole.

Aha. A grater, either of coral or iron, generally attached to the neck of a specially made four legged stool, used for grating the meat of mature coconuts.

Miti-haari. The most common sauce, made by expressing the milk from grated coconut meat and mixing it with sea water and lime juice.

Tai-oro. A sauce made of grated coconut meat, mixed with certain shell fish (*ma'o*) or with fresh-water prawns, and allowed to ferment.

Rau-ere. A fishing net, made by twisting together leaves of the coconut split along the rachis. The length of the *rau-ere* may exceed half a mile.

Tumu haari. The trunk of the coconut tree, used for building purposes.

It is perhaps significant to note that nearly all these words are found in the Dictionary of the Tahitian language, first prepared by the London Missionary Society in the early part of the nineteenth century. The word *niu,* given in this dictionary as a general name of the coconut tree, is not used in Tubuai. The same is true of a few of the other words with more specific meanings. On the other hand, I found no words applied to the coconut or to any of its parts or products that seemed peculiar to Tubuai.

Manioc Culture

Within the last ten years an increasing amount of attention has been paid in Tubuai to manioc. It now is the principal source of income of most of the people, besides being an important local food.

Sloping ground, not too dry, but well drained, is suitable for the cultivation of manioc. The ground is cleared, but not necessarily ploughed or spaded, and after planting, needs constant care to keep out the weeds. Manioc requires from one to three years to mature, according to the nature of the soil and the number of crops previously raised. When sufficiently mature, the roots are pulled or dug, and the stalks set aside for replanting, as manioc, like cane, grows from sections of the stalks. To prepare for use the roots of the manioc are scraped to remove the dirt and outer skin. They are then washed and grated. The grated root is placed in a bag, through which water is allowed to run, carrying with it the finely divided particles of starch, which settle in the bottom of the receptacle. These particles are later removed and dried, forming an excellent white starch, which finds a ready market in Papeete, besides being an important local food. The residue of the grated root makes a good feed for hogs and chickens. Manioc is supposed to have been introduced from South America to Tahiti and thence distributed to neighboring islands. Before the introduction of manioc into Tubuai, attempts were made to cultivate the pia but with only indifferent success. At present a few pia plants are to be found growing wild; and from time to time someone introduces fresh stock from the neighboring islands, but always abandons it in favor of the manioc. I was told that formerly there were two varieties of pia, one of which was quite

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poisonous if not properly treated. In preparing for food, the root, after grating, was subjected to heavy pressure to expel the poisonous juice and the dry residue washed to separate the starchy matter from the fiber. The product is said to closely resemble manioc starch to which also the term pia is applied.

Bananas

Small patches of well watered and drained land are devoted to cultivation of bananas, and rank growths were seen at numerous places in valleys not now inhabited. The cultivation of the banana requires little time and energy; the methods used in Tubuai do not differ materially from those employed elsewhere. It is said that fifty years ago only one variety of banana was known in Tubuai. Fourteen varieties are now recognized and named.

Fei. The so-called mountain plantain, an important food in Tahiti but not plentiful in Tubuai.

Meiatia (meia'tia). Two varieties are known by this name, differing only in length of the fruit. The longer is called *hai;* the shorter, *mari.* It is said that until fifty or sixty years ago these two varieties were the only ones known in Tubuai.

Puro imi. A variety characterized by a narrow leaf, short, thick fruit and small bunches.

Orea. The fruit is yellow inside instead of white. The sap from the cut stem of the young fruit is used medicinally.

Rio. The common "Chinese" banana of Hawaii, the most generally grown of all varieties in Tubuai.

Tai oura (tai o'ura). Tree, fruit, and leaf are reddish in color.

Tara puuatoro. The fruit is long and curved like a cow's horn.

Meia hamoa. Two varieties, one having long fruit and the other short; both supposed to have come from Samoa.

Meia taratoni. A very small, sweet fruit, commonly called a fig-banana, or simply a fig. Supposed to have come from New Caledonia.

Rau iva. A variety distinguished by its very large tree-like plant.

Poi tia. A variety whose fruit grows in small bunches, only five on the average, and at the top of the plant like *fei.*

Tara. There is only one plant of this variety in Tubuai; it was imported from Mangareva by Mr. Eugene Doom.

Bananas are generally cut while the bunches are still green, then ripened in some shaded place near or in the home. If a large number are wanted at some special time, as for a feast, they are cut three or four days in advance and placed in a pit with a few fruit of the *hinano*. The pit is filled in, care being taken to leave a cavity about the bananas. In from two to five days the ripening process is completed.

The *meia hamoa* and *meia rio* are the varieties prepared for drying and a considerable quantity are exported to Tahiti and the Tuamotu Islands in this form. The dried product is called *picre*.

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Fibers from the banana stem are sometimes used in weaving. The outer skin of the *fei* stem provides a black material sometimes woven into mats, hats, and fans as decoration.

Banana leaves are extensively used in lieu of table cloths and as inner wrapping in ti-leaf bundles of poi. The stem of the banana leaves, commonly called the tree, is an excellent food for cattle and is particularly used when stock is shipped to other islands. The stem is also used in the umu, where its function is to keep the food from burning, and to provide moisture for the steam cooking of the food. It is cut in sections of convenient length, beaten out flat and laid on the hot stones before the baskets of food are set in place.

Yams

At the present time the Tubuai people make little use of the yam, preferring in its stead the various similar food plants imported from abroad. The Tubuai names *hoi, pirita, uhi,* and *uhi parai,* indicate varieties of yam; the word *umara* is applied to yams and sweet potatoes in general. It seems probable that one or more varieties of yam have been known.

It is certain that at one time the *auti* or *aurii* was carefully cultivated in Tubuai, and that each household had its own patch of this important plant. At present there is little to be found. I had difficulty finding enough to make even a small amount of tapa and nothing could be learned of its culture in ancient times. The same may be said of the ava now practically if not entirely extinct in Tubuai. In former days breadfruit was a staple ranking with taro in importance. Now, there are few breadfruit trees to be found, and the fruit is not abundant. It is said, and probably correctly, that the trees have been destroyed by the horses. Even in former times breadfruit was not so important as in the Marquesas: there is no memory or tradition of its having been preserved in pits.

Minor Food Plants

Garden vegetables and miscellaneous food plants are not extensively cultivated in Tubuai, although it seems probable that most of the common vegetables could be raised if proper care were taken. Products of the modern gardens include beans, cabbage, capsicum, chickory, coffee, cucumbers, gourds, lentils, maize, watermelons, musk-melons, onions, papaya, peanut, potato, pumpkins, squash, radish, rice, sugar cane, sunflower, sweet potato, tobacco, tomato, vanilla.

Beans of several varieties are planted between the rows of newly planted coconuts; but most of the crop is wasted through neglect of the vines. Cabbage does not thrive.

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Capsicum is widely distributed, but little attention is given to its cultivation. There seems to be only one variety, the fruit of which diluted with coconut milk or water, is used in the preparation of a sauce served with fish.

Coffee has been planted in various places on suitable elevated slopes, and flourishes. After planting, the only care taken is to provide supports for heavily loaded branches, and to clear away the undergrowth to facilitate the gathering of the berries. The berries are hand picked and dried, but not hulled in Tubuai. Marketing is in the hands of the Chinese who export small amounts.

Gourds are cultivated to a small extent and are in demand for use as containers.

Maize is cultivated only as a garden vegetable.

The most common variety of papaya is used chiefly as hog feed, and is seldom cultivated after planting. The fruit is allowed to ripen and drop at will to be eaten by hogs ranging free, or is gathered and fed to hogs tied near the houses. A second variety, known as *iita vaihi,* supposed to have been introduced from Hawaii, is prized as food, but is not common. It is eaten raw, or combined with manioc starch and baked in the umu.

Peanuts are grown in small quantities from stock obtained in Tahiti. They are not important as food or as an article of export.

Pineapples of two varieties are recognized: one, known as *painapo popaa,* is of recent introduction from Tahiti; the other, known locally as the Chinese pineapple, is supposed by the natives to have been in Tubuai a very long time. The pineapple is not extensively cultivated, but flourishes, and is greatly esteemed, not only for use as food, but also for perfume: the fragrant skin is used in making *monoi*—(p. 18)—and in making wreaths for festal occasions.

Many unsuccessful attempts have been made to cultivate the Irish potato. An insect pest devours the plant, and the people are reluctant to use any poisonous spray lest the food be affected.

Sugar cane of two or more varieties is grown, but only in small patches for home consumption. It is used as food and also as medicine.

Rice has been planted in a few places, but without great care, and consequently without success. The Tubuai people prefer taro, and the Chinese are as yet too busy with their trading to care about agriculture.

Sunflowers were seen only in two very small patches, both grown from American seed. The plant flourishes, but as its only local use is as chicken-feed, it is regarded as almost worthless. Chickens, according to Tubuai belief, need no feeding! Two varieties of tobacco are cultivated in small patches in many parts of the island. The entire crop is consumed locally, most of it without special care in curing or aging. A small tomato is

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widely distributed on the island, growing without cultivation in newly cleared land. The food is esteemed, but not enough to justify the care necessary to properly cultivate the plant.

Vanilla requires too much care at the time of its fertilization to appeal to the Tubuai people. A few acres are devoted to its cultivation with fair success: and the Chinese traders export a small amount of the dried bean.

Oranges, lemons, and limes introduced from Tahiti, grow wild in various places, and thrive wherever they have been planted and properly cared for. The orange season is very short, but lemons and limes may be had the year around. The mango, guava, alligator pear, and grapes are represented by a few varieties.

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THE PEOPLE OF TUBUAI

RACE MIXTURE

The manner and the degree in which various racial stocks are combined to make up the population of Tubuai must await analyses of the physical measurements obtained. There are, however, fragments of history, genealogy, and tradition which throw light on the racial composition of the population.

Almost every person on Tubuai, excluding of course the Chinese, full-white, and other non-Polynesian residents, is more or less closely related by blood or marriage or both, with each and every other person. By casual adoption into a Tubuai family I became informally related to nearly all the people on the island.

That this state of affairs has not always existed is obvious from a consideration of early history and tradition, and from a review of genealogical tables. In the early days the various districts, although inhabited by people of the same general race, were constantly at war with each other. It is reasonable to assume close relationships existed within the districts, with occasional intermarriages between the districts during intervals of peace. Although the coming of Christianity broke down the barriers between these districts by stopping the warfare, there exists to this day a strained feeling between certain of the districts, and a tendency to avoid intermarriage.

For a long time Tubuai has received some immigrants from other Polynesian islands, not only from near by Ravaivai and Rurutu, but also from the more distant islands, including even Hawaii. There are at present in Tubuai people from Raivavae, Rurutu, Rimatara, Rapa, Mangareva, and from various islands of the Society, Tuamotu, and Cook groups. On the other hand, there is a remarkable lack of emigration. The Tubuai people say that they never have cared to leave their island, and that most men who venture into the world outside, return sooner or later to resume life in the old home. I have been informed by Mr. Stokes that in Rapa he found people from nearly every part of central and eastern Polynesia, but very few indeed from Tubuai. In Raivavae, the nearest of all the islands to Tubuai, the latest census shows only 11 people of all ages of Tubuai birth, while my records for Tubuai show about 20 Raivavae adults, in addition to many children. Likewise immigrants from Rurutu and Tahiti, and to a lesser extent from other islands, are well represented in Tubuai.

The influx of white blood began very early. It is not safe to assume the absence of white blood in any Tubuai individual today, and many have more than 50 per cent.

There is no record and no local tradition of a negro element. There are no Japanese, but the Tubuai population includes 9 or 10 full-blood male

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Chinese and a large number of half-Chinese. The prediction that in a few generations the Chinese element will dominate is by no means without foundation.

PHYSICAL MEASUREMENTS

Considerable difficulty was experienced in obtaining information regarding the physical characteristics of the people of Tubuai. The greatest objection was made to clipping the hair. The superstition still prevails that it is possible for evil persons to use a bit of hair in causing sickness or death to the owner of the hair. Nail parings, excreta, or even ornaments or parts of clothing may serve the purpose, but hair is to be preferred. The evil persons practising this art are supposed to be natives of Tuamotu Islands, and more especially of Hawaii. It required an infinite amount of patient explaining to persuade some of the people to part with the hair sample; and many, I am sure, were not entirely convinced that no evil could result.

Fortunately relations were established which permitted me to obtain physical measurements and hair samples of 135 adults and photographs of all but a few. These represent at least 50 per cent of the native population of Tubuai between the ages of 20 and 60. Several individuals each from Rurutu, Raivavae, Rimatura, Rapa, and the Society Islands were included, also a very few from elsewhere in Polynesia. The physical measurements have been transmitted for analysis to the Department of Anthropology, American Museum of Natural History. Characteristic facial types are shown in Plate III.

KINSHIP TERMS

Children generally follow the father, in name and family matters generally. If a couple separate, the oldest child or perhaps the oldest son will be considered as belonging to the father, the next to the mother, and the rest will be apportioned to suit all concerned. Adoption and temporary adoption are not infrequent, but not as common now as in former days. An adopted child has all the rights of a natural child.

In general, those persons of the same generation as the speaker are called brother or sister, there being no term meaning simply cousin. Younger brothers or sisters are distinguished, within the family group, but no such distinction is applied to cousins. Uncle or aunt are called father or mother, unless in reference there may be need of more definite term, when a descriptive phrase, such as "my father's younger brother," may be used. Similarly nephew and niece are called son and daughter, or in general, children. Full brothers or sisters are not ordinarily distinguished from half brothers or sisters. There are similar groupings, but descriptive terms or phrases are used when there might be misunderstanding.

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The large number of relationship terms noted are given as follows:

Parent-Child Class

Relationship Terms

English	Tubuaian	Remarks
parent	metua	no sex specified, used as singular or plural
father	metua tane	
	pa'ino tane	practically obsolete
mother	metua vahine	
	pa'ino vahine	practically obsolete
son	tamaiti	literally "little son,"
	tamatane	used formally only
	tama	obsolete
daughter	tamahine	
	tamavahine	obsolete, except in formal or legal usage
step-relatives	usual terms for parents and children	
foster-parent	metua ti'ai	not commonly used
feeding-parent	metua faa'mu	literally "feeding parent," refers to adoption
foster-child	tamaiti faa'mu	

The term *metua ti'ai* is infrequently used and only when absolute adoption is intended. I never heard *ti'ai* used in connection with the terms for children. In general, the foster child is regarded in every way as an ordinary child, and in direct address is always called son or daughter. Similarly, the foster parents are called, in direct address, father and mother. In reference if it is desired to be specific, the terms for feeding parent or child may be used, but otherwise the ordinary parent-child terms. An illegitimate child of a married person may be referred to as a *tamarii faaturi,* but only slurringly.

Grand-parent Class

English	Tubuaian	Remarks
grand-father (father of either parent)	tupunu tane	In general there is no specification of sex, *tupunu* being used unless there is possibility of confusion. In address, the personal name or *ruau,* meaning "old one," is used commonly.
grand-mother (mother of either parent)	tupunu vahine	
grand-child	mo'otua	If desired to specify the sex of the child, *tamaiti* or *tamahine* is added.
great -grand-child	hina	May add *tamaiti* or the proper sex term.
great-great-grand-child	hinarere	May add *tamaiti* or the proper sex term.

Inquiry failed to reveal any terms for progenitors farther removed than grand parents, or for descendants beyond great-great-grand-children. Descriptive terms are made up as needed.

Ancestors in general are referred to as *huaa* or more simply as *tupuna;* descendants are called *huaai.* All offspring of one couple are called collec-

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tively *opu taata,* and a particular family is sometimes designated as the *opu* of one of the parents, as for example *te opu arii,* referring to the children of the chief or king. A genealogy or recitation of one's ancestry is called *parau anatapapa* or less commonly *aihuaa.*

Sibling Class

TUBUAIAN	ENGLISH
tuaana	man's older brother
teina	man's younger brother
tuaana	woman's older sister
teina	woman's younger sister
tuahine	man's sister
tuane	woman's brother
tae'ae	man's brother or woman's sister

In referring to the sister of a female or to the brother of a male, the specific terms indicating relative age are almost invariably used. The term *tae'ae* is used rarely, generally only when the relative age is not known to the speaker. The terms *tuahine, tuane,* and *tae'ae* are never modified by words indicating elder or younger.

Half-sibling, step-sibling, foster-sibling, all are denoted by the ordinary sibling terms.

Spouse Class

TUBUAIAN	ENGLISH
tane	husband
vahine	wife
tane faaturi	lover
vahine faaturi	mistress
ari'i vahine	chief's wife or female chief or queen

It may be noted that *tane* and *vahine* apply equally well to the men and women living as husband and wife, but unmarried. The words are simply those for man and woman, or male and female. No terms were found for co-husband or co-wife. The term *tane faaturi* refers specifically to the lover of a married woman and *vahine faaturi* to the mistress of a married man.

Parent-in-Law Classs

TUBUAIAN	ENGLISH
metua hoovai tane	man's father-in-law
huno'a tane	man's son-in-law
metua hoovai tane	woman's father-in-law
huno'a tane	woman's son-in-law
metua hoovai vahine	man's mother-in-law
huno'a tane	woman's son-in-law
metua hoovai vahine	woman's mother-in-law
huno'a vahine	woman's daughter-in-law

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In reference the relatives may be more specifically denoted, if necessary, by descriptive terms. In direct address, the terms for parents and offspring are always used.

No other terms in this group were found, except a possible term for mutual parents-in-law (*apurua*) formerly in use, but now seldom heard.

In the grand-parent-in-law class only one term was found—that applying to the grand-child-in-law, without reference to sex, of either man or woman. This term, *huno'a mootua,* is seldom used, as generally descriptive terms or merely the personal names are used. In direct address the terms of the grand-parent class are used.

Sibling-in-Law Class

The term *taoete* was found applied both in direct address and in reference to all members of this class, including: man's wife's brother or sister, and their respective mates; woman's husband's brother or sister, and their respective mates. Descriptive terms may be employed to more definitely denote the person referred to, but in Tubuai where the population is so small that any person is readily recognized by name, the personal names are more likely to be used.

Uncle-aunt and Nephew-niece Class

Any male relative in the same generation as the parents is referred to and addressed as father, the term *metua tane* being used, and similarly any corresponding female relative is called *metua vahine*. All relatives in the same generation as the children are referred to and addressed as are the true children.

Cousins, direct or cross, call each other brother and sister using the proper terms in the sibling class.

Spouses of aunts and uncles, and of cousins, are denoted by the terms for their proper sex in the classes of their mates. The inclusion of such relatives by marriage is rarely extended beyond the most nearly related groups.

GENEALOGICAL TABLES

At the time of my stay in Tubuai many of the more important families were involved in disputes about land titles. The people were therefore quite reluctant to give out any information about their ancestry, as French courts in Tahiti and the neighboring islands recognize the ability to recount family connections for a number of generations as practical proof of membership in that family, and settle land disputes accordingly. I was therefore unable to obtain for publication any full genealogies. There is no question that genealogies covering 20 or more generations are in existence. I am personally

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familiar with two such genealogies, and I hope that at some future time permission may be granted to use them. From various sources I have compiled five genealogical tables which include members of seven generations, obviously too short a record to be of high value in writing the early history of Tubuai. It seems desirable to withhold them from publication until material which permits their extension is available.

SOCIAL ORGANIZATION

Distribution of the Population

Three of the ancient villages of Tubuai have been succeeded by modern villages, located on very nearly the sites of the earlier settlements. Toerauetoru is now Mataura; Natieva is Taahuaia; Nahitorono is Mahu. The names Toerauetoru and Natieva were furnished me by Tautua Mauritera, a Tubuai man with considerable knowledge of the history of his island. The Teehu manuscript corroborates this information. It is interesting to note that Tautu was uncertain as to the name of the ancient settlement at Mahu, and gave the name Naraieha. From the Teehu manuscript (47) it appears that a Raivavae man, Narai, invaded Tubuai some time in the latter part of the seventeenth century, and settled at a place then called Nahitiorono. To this village the name Mahu was subsequently given, because of the *mahu*, or hermaphroditic son, of Narai. The clan of Narai was called Naraieha. Thus Tautu's uncertainty and his giving the clan name of the settlers instead of the former name of the village seems a strong confirmation of the Raivavae account.

In addition to these three settlements, represented by modern villages, there were at least two villages now no longer in existence. Tuporo, not far from the present settlement of Haramea, and Paorani, inland and to the east of Taahuaia, are still to be seen, but only as scattered stones of the ancient house sites and marae enclosures and pavements. A settlement of some sort existed in the neighborhood of the present village Huahine, but its name and location are not now known.

The evidence shows that in former times there were five principal centers of population: Toerauetoru, Natieva, Nahitorono, Tuporo, and Paorani. There was a settlement near or at Huahine, one of slight importance near Tamatoa, and perhaps others of which no trace can now be obtained. The configuration of the island limits the lands about each of these centers: ridges of the mountains, borders of the swamps, and banks of streams form natural boundaries. (See map, Pl. I.) The district centering about what is now Mataura was bounded on the east by the ridge of Mount Taitaa, terminating in the point of black rocks at the beach; on the west, by the stream emptying into the lagoon opposite the wide pass in the reef; on the

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southern or inland side by the rather vague line of swamp-border and mountain ridge forming the disputed northern boundary of Huahine. The district about Huahine was hemmed in by mountains on the east, swamp on the west, and the lands of presumably hostile clans on the north and the south. Whether or not the people of Huahine ever had access to the sea is not known; a little light was thrown on the question by an informant who stated that the surest way for an inhabitant of Mataura to commit suicide was to venture too for inland toward Huahine: that the old-time inhabitants of Huahine were *etene mau* (heathen indeed).

The position of Tuporo is particularly notable. All sides of the mountains at the western end of the island, where they slope down into the level lands, show evidence of having been extensively cultivated. Terraced walls of ancient taro patches, remains of maraes, and in particular the many trails connecting all parts of this section, show how numerous and active the people must have been. Several of the trails were paved in wet and in stony sections, so as to afford easy going for bare feet. Horses find these trails so difficult that several such paved stretches have been abandoned as unsafe, especially places where stepping stones have been laid for passage across some stream or bog. It seems clear that this isolated region, practically cut off from the rest of the island by swamps but crossed and recrossed by good trails, must have been occupied by one clan or by clans on friendly terms. The only region from which Tuporo is not well separated by natural features is that about Huahine, whose inhabitants must have been either exceptionally powerful or else have been reduced to utter subservience, as their lands were quite unprotected by nature from the peoples to the north, south, and southwest.

The relative size and importance of the ancient settlements is not definitely known. It seems likely that Mataura, or Toerauetoru, was the largest, with Tuporo a close second. In the old days the village of Toerauetoru centered about the residence of the chief near the river at the western end of the district. The first missionaries built a church near the one now in Mataura, not far from the eastern end of the district. The people gathered about this as center, which accounts for the present village site. A long unused road leads up toward Huahine from the site of the former village; a second, from a point about midway along the coast between the old and the modern sites but the principal road across the island now begins at the present site of Mataura. The very important marae Tonahae and several of lesser importance were within the district of Tuporo. The last king of Tubuai, reigning when the French took possession of the island, controlled the entire district, and even now certain lands used for public purposes are recognized as the property of his estate. These facts unite to indicate

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Mataura, or Toerauetoru, as the principal settlement or district in former times. From archaeological and legendary evidence the others, according to lessening importance, stand in this order: Tuporo; Taahuaia, or more properly Natieva; Nahitiorono, now Mahu; Huahine, Tamatoa and Paorani. The geographical conditions suggest that the region about Taahuaia was all one district; but tradition relates that a battle between two clans took place at the present site of Taahuaia, the home of the victorious clan being Paorani. Paorani may perhaps have been of more importance than Natieva. It is assigned a subordinate position because of lack of information of any sort other than the tradition just mentioned, and the location of only a very few, widely scattered remains on its site. Nahitiorono cannot have been very large, as it was easily conquered by the Raivavae invaders under Narai, who very soon completely dominated the section. Tamatoa is given a subordinate position because of the utter lack of evidence of an extensive settlement at any time. There are now only a few houses, not grouped in a village, but scattered about on the lands of their owners.

The evidence indicates that in ancient times the population of Tubuai was grouped within more or less definitely limited districts, with centers of population within the districts perhaps deserving the name of villages. There is nothing to indicate any extensive village life and it seems likely that the association of neighbors within a relatively small area was rather a protective measure than a manifestation of desire for community life. Each family seems to have had its own house site on land controlled and farmed by the family; its own marae, and its own place of burial, either associated with the marae or separate. The life of the district centered about the residence of the chief and perhaps the principal marae. Village life, to the small extent that it has developed, is presumably due to the influence of the missionaries, the people gathering about places where the teachers established their headquarters and later their churches. It is possible that excavation of the village sites may show a community organization more highly developed than my studies indicate.

Government

At one time Tubuai was ruled by a king, with chiefs representing the several districts of the island. Legends and fragments of historical evidence indicate that in still earlier times more power was vested in these local chiefs and that at times there was no real king. During such times one chief would attempt to vanquish those less powerful, and if successful, would rule the whole island until overthrown by another chief. A legend of Tahiti deals with "the chiefs of Tubuai"; a legend of Tubuai refers to war between two groups of peoples on that island; an old Tubuai man stated that in his great-

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grandfather's time there were three principal districts on the island, each with its independent people; a certain patch of land near the village of Mataura has not been used since the time when a battle was fought there between the people of that district and those of the neighboring district to the east; a Raivavae man told me that in early days the king of Raivavae went with some followers to Tubuai, married a Tubuai women, and established a ruling dynasty which for generations controlled the entire island. Other legends indicate that heroes from Tubuai invaded Tahiti, Rurutu, and Borabora; and that heroes from Tahiti and the Tuamotus invaded Tubuai. Historical accounts state that Tubuai was peopled from Raivavae in the latter part of the eighteenth or the early part of the nineteenth century. All the evidence points to great political unrest before the early missionary days, to continual wars both between districts on the island and between Tubuai and other islands, and in general to a political state such as prevailed in the Hawaiian group before the days of Kamehameha I.

The island is now a French possession, and as such is subject to the laws governing French colonies. The administration of these laws is largely in the hands of a resident French gendarme, although theoretically a certain amount of power is vested in the local governor and the council of Tubuai men who elect him from their own number. Taxes are levied and collected, either in cash or in labor. This labor is sufficient to keep the roads and bridges in reasonable condition, and to care for the Government buildings and grounds, which consist only of the school house, the gendarmerie, and a small amount of adjacent land.

Division of Labor

There seem to be few hard and fast rules governing the division of labor between the sexes, yet certain occupations are clearly recognized as essentially woman's work, others as man's work. Naturally the more arduous and dangerous tasks fall to the lot of the men. Among these are felling of timber and building of houses, construction of roads and bridges, clearing fields of tangled wild growth, making of taro patches, up to the actual planting, making of sennit and rope, spear fishing and fishing from canoes, canoe making, navigation in general, making and opening of the native ovens, killing and dressing of animals, and a few minor tasks of such a nature as obviously require a man's effort. Work performed by women includes weaving lauhala mats, hats, and baskets; care of the house; making and washing of clothing; care of children from the prenatal preparations through birth and on to such a time as personal care no longer is tolerated by the growing child; making of tapa (now obsolete); gathering the marsh grass used as floor covering, and various similar minor tasks.

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Both sexes work in the taro patches. It is felt, however, planting, weeding, pulling the mature plants, and in general caring for the patches is more properly man's work, and visitors from Rurutu joke the Tubuai women on this account. It is not unusual for women to walk along the reef, fishing with pole and line, or gathering sea forage of various sorts. That such an occupation was formerly considered improper for women is indicated by the fact that the word *manuaiaihaa,* now obsolete, which was used for any insect or animal that fed on filth, was also applied to a woman who fished on the reef. The preparation of food is the work of both sexes; *popoi* is usually made by the men; the food placed in the oven may be prepared in bundles by either men or women, but is arranged in the oven by the men; fish and fowl are prepared by the women, but animals are butchered and dressed by the men. Whether or not the men assist in ordinary home cooking is a matter of convenience, but in general they have nothing to do with such work. The training of horses is man's work, but women and girls frequently ride partially broken animals. Making of copra and of starch from manioc are occupations of both sexes, young and old. In short, with the exception of a very few tasks, the division of labor is no longer marked, but there can readily be traced a feeling formerly which was much stronger than it is today.

In political affairs women never appear, although they no doubt indirectly influence the men. There is no woman's suffrage movement. Many women own property, and a family house or the land upon which a family depends for its taro is as likely to belong to the mother as to the father. In the community life women perform services quite as important as those of the men. Medicines and medical treatment are prescribed and administered by either. In mass meetings the women as well as men are called upon for opinions. There is cooperation in the heavier household tasks showing that women are by no means treated as inferiors or slaves. Respect and consideration are the due of women to quite as great an extent as of men. In the home, ordinary domestic duties fall to the lot of the women quite naturally. Many business deals depend on the word of the women of the family, and many men bear unmistakable signs of being sadly henpecked. It is probably fair to say that the Tubuai household is as much ruled by its mistress as is the average American household.

Sex Life and Marriage

In regard to matters of sex, the attitude of the natives of Tubuai differs from that taken by the foreigner in general. To the Tubuai person, it seems that sex relations which intimately affect none but the two involved may be dismissed from thought as the concern of only those two persons; that there is sin or crime or wrong only if some other person is concerned,

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as when husband or wife commits an indiscretion with a third person. It is exactly as though a person, hungering, accepts food offered; if the consumption by him of that food wrongs no one, if that food belongs to no one else, no harm has been done. When this attitude of mind is recognized the various apparent irregularities are readily understandable.

Sex life begins with the male at the age of from 13 to 16, at some time within which period he is circumcised in Polynesian fashion. This operation constitutes his informal initiation into manhood; no puberty ceremonies are conducted and no tapu rites are enforced in this connection. The boy will then consider himself a grown man, and will take advantage of the first opportunity offered to test his powers. This opportunity is generally offered by a girl of like age, and may be repeated as only casual intimacy for several years. There is no ceremony of any sort connected with a girl's maturing; the first menstrual period is not marked by any tapu, and her first sex experience may or may not have preceded this stage in her life. It is usual for a girl to accept a lover's attention at the age of about 15, and the boy concerned may be as young. The young couple will live together more or less openly, and after a few months or years marry or simply set up their own household without sanction of the ceremony. It may be, on the other hand, that after this "trial marriage," or informal cohabitation, they will not be satisfied with each other, or will meet with the opposition of their relatives. They will then seek other mates. A girl who has had a lover will generally not marry any other than him, but if she leaves this lover may go to live with another and continue as his mate for many years. In Tubuai not more than half of the couples are married; there seems, however, to be no stigma attached to those who are not, and certainly the unmarried couples are quite as faithful and likely to remain together as those bound by law and church. There are very few divorces; I did not hear of a single person actually freed by process or law or church. There are, however, separations by mutual consent, leaving either of the two concerned free to take a new mate.

There is a general feeling that it is better and more nearly in accordance with the teachings of the Bible to be lawfully married, and the fact that only married or sinless persons may take communion shows observance of this feeling. Incidentally it may be remarked that those other than married people who take communion are very few in number. At the same time it is not regarded as at all disgraceful to live as man and wife without sanction of law or church, unless one or the other of the persons concerned is habitually wayward.

It is recognized that in former times, before the French law was imposed on these islands, regular marriage was far more common. The contracting parties simply went before the chief of their district or before the king, if

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there was such, and announced their intention to live together. His word of approval sanctioned the union; if later they desired freedom, they again sought their chief and explained matters, and again their actions were sanctioned by his approval. Just exactly what ceremonies may have accompanied these marriages and divorces could not be ascertained, as there are no people living who were married by the old form.

Descent and Inheritance

Descent is ordinarily counted in the male line; a genealogy is reckoned from son to father, and on back, unless it so happens that there has been a break in a line of descent. For example, if a chief has no sons, his eldest or favorite daughter will carry on the line through her oldest son. It is customary to reckon the family along one line only, but if there are important ancestors in other than the direct line, they also may be mentioned in a recital. It was impossible to obtain in Tubuai any of these family records beyond a few generations, as not many can recite their genealogical tables. Those who can will not do so.

Inheritance generally follows descent, but apportionment does not necessarily imply actual division, so that certain lands are recognized as the property not of an individual occupying them, but of the family of which he is one member, he having perhaps life interest in them. For example, a white man residing at Mahu, Tubuai, is offering for sale a tract of land given him by his wife, and duly recorded in proper legal form, but is occupying a house upon another piece of land, which upon his death will revert to the family of his wife.

The only safe way for an outsider to obtain a piece of land is to buy from the French Government land that has been forfeited for failure to pay taxes. Otherwise a buyer may be obliged to satisfy separately the claims of a large number of people, related to and joint owners with the person who seems to have full title at the time of sale.

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FOOD AND ITS PREPARATION

MATERIALS USED

It is said in Tahiti that nowhere in the world are fish so plentiful or of as great variety as in Tubuai. I believe this statement so far as this part of the Pacific is concerned. In fair weather there is scarcely a day when any family on the island lacks fish; one man readily gave me the names of more than 60 different fish. (See p. 11.)

With only one or two exceptions, the fish are edible. Shell fish are ordinarily scorned as food, but in emergencies or for variety in diet, the *pahua,* a large bivalve, the *poreho* and various others are eaten. The few clams to be found are considered not worth the labor of digging. Eels (*puhi*) although abundant in fresh water, are not eaten, and the salt-water eel, which attains considerable size, is regarded as poisonous.

Crustaceans are prized as food, but are not plentiful. The spiney lobster (*oura miti*) and a fresh water prawn (*oura pape*) are sometimes taken. Sea crabs are not eaten, but the land crab (*tupa, Cadisoma carnifex*) is considered excellent, when captured at a distance from human habitations. The coconut-crab is not found in Tubuai.

Of the five varieties of seaweed recognized by name, *rimu otaha, rimu tu,* and *rimu opupu* are edible, and are occasionally used as salad; *rimu paûa* is sometimes eaten, but *rimu ohena* is considered inedible. Seaweed is never cooked. A variety of fresh-water plant similar to watercress is also eaten.

Chief place among vegetable foods is held by the taro. Second only to taro is the coconut. Bananas have attained a high place in the list of Tubuai foods only within recent years. Yams and several varieties of sweet potatoes are important food items, and being easily stored and handled are especially adapted to the use of sailors.

Meat is of relatively slight importance as an article of food. Cattle are raised, but are regarded as too valuable for home consumption. During my stay in Tubuai only one animal was killed for beef, and it appeared later that the killing was timely; in another day the cow would have died of natural causes. A very few cows are kept for milking, but the milk is of poor quality. Most of the milk, and likewise most of the beef consumed on the island, is of the tinned variety, and is regarded as a luxury. Pigs are raised in large numbers for export to Tahiti, but occasionally one is killed for home consumption. A feast is not complete without roast pork. Some of the more provident families salt away pork when it is necessary to kill a pig, and thus have bits of meat during a period of several weeks. More commonly, however, if the pig butchered is larger than the family can dispose of in one or two days, the surplus is peddled to the neighbors.

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There was a time when wild goats were plentiful in Tubuai; but very few remain. I was told that there were not more than ten wild goats on the island. A very few are domesticated; the natives really do not care for the meat, and apparently make no use of the milk. Sheep were introduced but did not thrive. Horses, dogs, cats, rats, and mice, the only other animals, are not now used as food, and no one would admit that any had ever been so used.

Poultry is plentiful, and is a staple article of food. Turkeys are raised, but, like pigs, bring such good prices when exported to Tahiti, that few are killed for home use. The same is true to a less extent of ducks and geese. Chickens thrive with little attention and appear frequently on the table of almost every household. Few eggs are eaten, as the hens do not lay well, and running almost wild as they do, are able to hide their nests quite effectively.

HOUSEHOLD UTENSILS AND PREPARATION OF FOOD

Modern utensils, to a considerable extent, have replaced the ancient ones for the preparation and serving of food. Yet side by side with the earthenware and iron basins purchased from the Chinese stores are bowls of coconut shell and platters and troughs hollowed out of wood. Anyone can find a tin can in which to boil water, yet when my informant described the preparation of a certain medicine, she specified that to heat it for application, a hot stone must be immersed in the mixture and left until the desired temperature is attained. And so throughout with the preparation of food: old methods and old utensils persist, in spite of the greater convenience of modern things.

Coconut shells and gourds are used as cups, bowls, and bottles or storage jugs. The coconut shell ordinarily used as a bowl is merely a half nut from which the husk has been stripped and the meat removed by a scraping implement. Such shells are discarded after a single use. If used as a bottle the mature nut is husked and cleaned. A cord, generally of sennit, is attached through one of the eyes, and a plug may be fitted to stop the other. At present few are in use, as gourds are more commonly preferred because of their greater capacity and because of the difficulty of working the hard wood of the coconut. The gourd is generally used in its entirety, only a small opening being cut in the top or the end of the neck. This opening may be small, and fitted with a plug, or large, and provided with a cover, depending on the use for which the gourd is intended. The base of a gourd, cut so as to form a shallow, circular bowl, is sometimes used as a dish or basin. Gourds split lengthwise were not seen, but I was told that formerly they were used as platters. Most gourds used as containers were provided with sennit, netted tightly about them and provided with handles for carrying or hanging (Pl. V).

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Trough-shaped wooden bowls of all sizes, from 18 inches to 6 feet in length, and correspondingly deep, are cut from solid blocks of wood, and used for the preparation, serving, and storing of food. (See Pl. VI, *A*.) Some of these bowls approximate shallow platters in shape; others are more truly trough- or canoe-shaped. Most of these bowls are carved with a lip or spillway at one end, and a boss or handle at the other.

Coconut grating stools are more or less carefully carved seats, with four legs and a projecting neck to the end of which is bound the grater—a piece of coral or of iron. The operator sits astride the stool and, holding the nut in both hands, rasps it on the stationary grater.

Poi pounders are made of coral, shaped while fresh from the ocean. Formerly harder stone was used (p. 162). Poi boards resemble heavy, low tables, 3 to 5 feet in length, about 18 inches wide and resting on legs 4 to 8 inches high. The board and legs are carved from the same block of wood.

Scrapers for preparing taro and other foods are made by grinding down one edge of a piece of coconut shell, or by similarly grinding one valve of the *pahua* (*Tridacna*). If available, the top of a tin can is preferred.

Commercial knives are in general use. For some purposes, however, the bamboo knives have not been entirely supplanted. A pig is very likely to be stuck with a long, tapering splinter of bamboo, and part of the butchering may be done with the same or a similar implement.

The native oven is described by Amich (2, pp. 83-84).

> They [the natives] make a big bonfire in a pit wherein they set a lot of stones; whilst these are getting heated they do up the paste dumpling and everything else they want to cook, in a quantity of large leaves, and afterwards pack them into small frails of palm-leaf. As soon as the stones are thoroughly hot they are raked aside from the pit and they lay the baskets in on top of the embers; and over these the hot stones [are spread again]. Lastly, they cover in the whole with earth in such wise that no air-hole is left anywhere. Next day they open it all up, and have thus enough food ready to last them for quite a many days.

Amich does not mention the use of crushed sections of the stalk of the banana palm, which are spread over the embers and hot stones in the pit before the bundles of food are put in place, and which serve to keep the food from actually burning. And no reference is made to the small mats of hau leaves, used as insulating material over the hot stones after their replacement in the pit and to keep the earth from filling in around the packages of food. Yet in all essentials the description by Amich applies to the Tubuai oven now in use and is proof that little if any change has been made in this method of cooking during the past 150 years.

Articles of food that may be cooked in the umu include fish, pork, taro, breadfruit, sweet potatoes, prepared poi of various sorts, and in fact almost any article of food. Chicken and fowl in general, certain sorts of fish, rice,

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and the various vegetables of foreign introduction, are generally boiled, and taro as well, unless an oven is being prepared for other things. It is no little labor to properly prepare an umu, and consequently the easier method of cooking is frequently used, even when it is recognized that the umu method would be better. On Saturdays it is customary to prepare the next day's supply of food, and place it in the umu, so there may be a minimum of labor on the Sabbath.

Preparation of food for consumption does not necessarily involve cooking. Certain varieties of fish are preferred raw, and shell fish are more frequently eaten raw than cooked. Lobsters and crabs are always cooked, but shrimps and the small shellfish known as *ma'oa* are generally mixed with a fermented coconut sauce (*taioro*) and eaten raw. The preparation of raw fish for the table is simple. As soon as possible after it is caught, the fish is cleaned, scaled, and cut in strips or pieces of convenient size. After lime juice has been poured over them the slices are set aside for an hour or more, until the lime juice has been thoroughly absorbed. They are ready to serve, with a sauce made of coconut milk and sea water (*miti haari*), or may be put away in gourds filled with a fermented coconut sauce (*miti hue*). The fish stored in gourds is supposed to be better after a day or two in the sauce, but the average foreigner does not agree with the native in his estimate of this delicacy. Certain fish, slightly larger than sardines, are eaten with relish just as they come to hand, and the same is true of a bivalve (*pahua*) and of a species of *Turbo* (*poreho*).

The *popoi* of Tubuai is exactly the same as the Hawaiian poi, and is prepared by pounding cooked taro with a stone pestle, adding enough water to form a smooth paste, of consistency to suit the individual fancy. Very ripe bananas are frequently crushed and mixed with *popoi*. The bananas so used are frequently ripened by being stored for a few days in a covered pit with a few ripe cones or fruit of the hala (*hinano*). The food known in Tubuai as poi is prepared manioc starch, combined with papaia, bananas, cooked pumpkin, or *fei*. The fruit is first crushed, either with the hands or the pestle, then a small amount of the starch thoroughly mixed with it. The mixture is wrapped in ti leaves and banana leaves with hau bark strips to reinforce and tie the larger bundles. The bundles are then placed in the umu, and cooked for an hour or longer, usually overnight. The poi when cooked has about the consistency of stiff gelatin pudding; it is cut in small pieces and served with fresh coconut milk as sauce. Poi is also made by grating the raw taro or manioc root, with which fruits are sometimes mixed to give flavor. A full description of all the kinds of poi would fill a fair-sized cookbook; it is a most important item in the Tubuai dietary.

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FIRE MAKING

The process of making fire with the fire plow is understood by most adults in Tubuai, but the younger generation in general is not learning the knack and within a few years it may be a forgotten art. The process was demonstrated to me as follows: (See Pl. XII, *A, B.*)

The operator selected a stick of dry hau, 3 inches thick and 1 yard in length. With his teeth he split off a small section to use as a plow; the remainder served as hearth. He seated himself on one end of the hearth, turning the flat side up, and held the opposite end firmly on the ground before him with his feet. Holding the plow near one end with both hands, he moved the opposite end with moderate pressure forward and back along the hearth, the plow making an angle of about 45 degrees with the hearth. The position of his hands, and the manner of holding and manipulating the plow, suggested very strongly a carpenter manipulating a large chisel when sharpening it on an oil stone. After about two hundred strokes at the rate of two a second, a little wood-dust began to accumulate on the hearth where the plow strokes ended. The operator later demonstrated that had he rubbed the end of the plow in sand or earth before commencing the operation, the dust would have accumulated more quickly. When the wood dust was first noticeable, the rate of plowing was doubled for thirty or forty strokes. The dust then began to smoke, and after fifty additional strokes at a still faster rate, to glow. The plowing was stopped and the glowing dust flicked off into a bit of tinder, held in the operator's right hand. By gently breathing on the glowing mass he soon had it in flames. From the moment the hearth was laid in place to the actual firing of the tinder was only two minutes, twenty seconds. Subsequent trials with fresh materials were successful in from five to thirty seconds less time.

Dry banana leaf or other dry vegetable matter is used for tinder, and even when everything seems saturated by rain, some such material can be found. My housekeeper never seemed to mind the wet firewood, but kindled and fed the fire with apparently as great ease when everything was wet as when conditions were more favorable. A fisherman or voyager in a canoe can readily obtain fire by splitting a small plow from his paddle, and using the blade as hearth. Maui, the legendary culture hero, is said to have concealed the fire in his paddle when he first brought it to the Polynesian people. Hence it is entirely natural, my informant stated, that paddles may always be made to yield fire, and since Maui's paddle, like most of those in use ever since, was of hau, that wood is naturally most suitable for use as hearth and plow.

Flint and steel were introduced into Tubuai at an early time, and are still used, though very rarely. Matches are obtainable everywhere, and consequently all other methods of fire-making are useless except in emergencies. I found no evidence of fire being specially prepared for particular occasions, nor of any sacred or ceremonial character being attached to fire or its kindling. The nearest approach was the idea that nothing intimately pertaining to the person, such as hair clippings, nail parings, and excreta, should be burnt, lest misfortune befall the person concerned.

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PRESERVATION OF FOOD

The Tubuai people sun-dry fruits, beans, various grains and also fish, bananas, and copra. Articles to be sun-dried are placed on racks erected in open spaces near the beach, or in shallow water near the shore. The object of erecting the racks in the shallow water is twofold: to obtain the maximum drying effect, and to protect the food from rats. Copra is dried both before and after its removal from the nuts. The split nuts are spread on the beach or hung on racks, and the meat is later spread on trays, which are laid on the ground or on the racks.

The original method of pickling seems to have been to place the food in storage gourds and cover it with brine or fermented coconut sauce. This is still a favorite method when there is an excess amount of fish to be disposed of, and the food thus preserved is considered (by the native) excellent even after several days. The better method, that used when fish or pork is to be kept for some little time, is salting. The meat or fish is prepared by cutting into strips, rubbing thoroughly with salt, and storing in wooden troughs, kegs, or other suitable containers. Commercial salt is now used; formerly, small amounts of salt were obtained by evaporating sea water.

Dried bananas are kept for months by carefully wrapping convenient amounts in strips of banana or *fei* bark. The ends of the bark strips are brought together at the ends of the bundles and tightly tied, making the finished bundles roughly cylindrical, not unlike Mexican tamales in shape. The mixture *popoi* (p. 40), made with the least possible amount of water, is kept for weeks by carefully wrapping in ti leaves. Such bundles, reinforced by further wrappings of hau bark, are shipped to Tahiti and to islands in the Tuamotu group when opportunity affords, as the Tubuai product is greatly in demand in those places. Other articles of food are wrapped in ti leaves for cooking, for temporary storage, or for transportation, but only dried bananas and *popoi* are preserved in such manner for considerable lengths of time.

DRINK

Ava was formerly used as a drink in Tubuai, according to all local informants, but the missionaries abolished its use after their arrival in 1822. There are now very few ava plants to be found on the island, and I could not obtain definite information as to the extent to which the drink had formerly been used. It is not mentioned in any of the Tubuai legends that I heard nor in any published accounts of visitors to the island. I believe its use to have been relatively slight.

A mildly intoxicating fermented drink is made of bananas. The ripe fruit is cooked and crushed, the juice strained and decanted into bottles or

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gourds and set aside for a week or more. A similar drink is made of oranges. A sort of beer is occasionally made with honey and imported hops as the principal ingredients, but its preparation is regarded as too bothersome. These drinks are all strictly forbidden by the French laws.

The consumption of imported alcoholic beverages is confined by law to the French gendarme and to a few others who have obtained special permits. On state occasions, such as the time of the 14th of July celebration, laws against alcohol are decidedly relaxed, but at other times there is practically no drunkenness on the island.

Coffee is not a favorite beverage. Tea is almost never used, except by the Chinese. Sometimes infusions are made of orange or lemon leaves, and certain grasses are considered as fair substitutes for tea leaves, but in general hot or warm drinks are not esteemed. The everyday beverages of the people are fresh water and the water of green coconuts. Every home that boasts a galvanized iron roof has a barrel or other receptacle for rain water. Drinking water is also carried from certain special places on the streams where there is supposed to be no contamination. There are a few springs, and some shallow wells, but the well water is generally brackish and unfit for drinking.

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PERSONAL ADORNMENT AND CLOTHING

MUTILATION OF THE BODY

In the mind of the Tubuai man or woman personal adornment is a very important matter, and seems to concern them more than houses or mere clothing.

Tattooing is not practiced in Tubuai at the present time, nor is there any living native whose body is so decorated, excepting those who have as sailors visited other parts and followed sailors' customs by having tattooed their names or initials and various modern patterns. There is some difference of opinion in Tubuai as to the extent to which tattooing was formerly practiced. I was told of two men and one woman, all of whom were living ten years ago, whose bodies were decorated in the ancient manner, but no one could describe the designs. These three persons are supposed to have been natives of Tubuai. The immigration from many other parts of Polynesia into Tubuai has been so extensive, however, that I am inclined to give little weight to this evidence. Ellis (20, p. 54) mentions a Tubuai man, whom he supposes to be a chief, as being "but partially tattooed." This statement may be taken as evidence that the art was known in Tubuai (1817), whether widely practiced or not.

Many of the Tubuai women make a practice of plucking out the hair in the axillae. The reason that they give is that the hair causes an unpleasant odor; to the Polynesian, odors are very noticeable and important. I saw two methods used: the simpler consisted of extracting the individual hairs by means of the thumb nail pressed against a bit of hard wood or shell, primitive tweezers. The other method is more painful, but effective. Gum from the breadfruit tree is smeared over the area to be denuded of hair, and allowed to remain until partially hardened. It is then pulled away with a series of sharp jerks, taking with it all the hair and a few stray bits of skin.

Facial hair is of little consequence to most of the people. Very few women have even the slightest trace of hair on their faces; and most of the men are likewise unadorned. Some men have slight growth on chin or lips, and a very few have had facial hair like that of the average white man. Many men never shave, yet have not even the suggestion of a moustache. Those who shave use the modern razor, and no native has knowledge of any primitive substitute.

I do not recall seeing a woman or girl over six or eight years of age whose ears were not pierced for earrings and only recently have the men abandoned the practice. Many middle-aged and elderly men have pierced ears, even though they never wear earrings.

The ears are pierced when the girl is very young. The process is simple: a thorn, generally from a lemon or orange tree, is thrust through the lobe of

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the ear, into a soft bit of wood held against the opposite side. The point and base of the thorn are then broken off, leaving the intermediate section in the wound to keep it open until healed. Sometimes a coarse needle, with heavy thread, is used to pierce the ear, a bit of the thread being left in place to keep the orifice from closing in healing. In former times it was customary to enlarge the opening sufficiently to permit wearing flowers or other ornamental objects.

It is believed, in Tubuai, that a round head is normal and ideal. Unless an infant's head is unusally long, the mother or some attendant whose skill in such matters is recognized, will generally attempt to mould it to the desired shape. Gentle pressure is applied with the hands at intervals, beginning very shortly after the birth of the infant and continuing through the first week or ten days of its life. I have no doubt that this treatment actually modifies the head shape of most of the infants. Just how much it affects the development of the skull and its final form is uncertain.

HAIRDRESSING AND HEAD ORNAMENTS

The chronicler of Cook's last voyage (15, vol. 2, p. 6) notes that at Tubuai some of the men wore their hair "tied in a bunch on the crown of the head." He mentions no head covering or wreaths. Ellis (20, p. 376), who likewise mentions the tying up of the hair, states that many "wore large folds of white or yellow cloth bound around their heads, in some degree resembling a turban."

In modern times the people of Tubuai give more attention to the care and dressing of the hair and the ornamentation of the head than to any other part of their dress. The average Tubuai person has beautiful hair, and an abundant supply. Few persons are even slightly bald, none fully so. Both sexes keep the hair moist with *monoi* (p. 18). The men comb and part the hair, wearing it short in ordinary fashion. The women comb the hair straight back from the forehead, and generally braid it in one or two braids. Hair ribbons and ornamental combs are generally used by the women, but not hairpins. Flowers are frequently worn, thrust behind the ears, or twisted into *hei* (wreaths), fitting about the crown of the head. Men and women of all ages delight in such decoration, but naturally it is the adolescent children and the young adults who most frequently indulge. Wreaths of shells from the Tuamotu Islands are highly prized. (See Pl. III, *A. C.*)

Hats are worn by all except very young children and babies, but only in the daytime. No one thinks of covering the head at night. These hats are all of native manufacture, and are decorated with ribbons, artificial flowers or other decorations supplied by the Chinese traders, or with natural flowers twined into wreaths. A man must remove his hat in church, but a woman never does. Wreaths are never worn by either men or women in church,

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and a woman considers flowers inappropriate decoration for a hat worn in church. A man does not generally tip his hat when he meets a woman, but may remove it while talking with another man, particularly if he has some feeling of respect due to a difference in age or in position.

CLOTHING

When Captain Cook visited Tubuai in 1777 (5, vol. 2, pp. 6-7):

> [The natives] had no covering but a piece of narrow stuff wrapped about the waist and made to pass between the thighs, to cover the adjoining parts; but some of those whom we saw upon the beach, where about a hundred persons had assembled, were entirely clothed with a kind of white garment. We could observe that some of our visitors, in the canoes, wore pearl shells, hung about the neck, as an ornament.

Modern jewelry has replaced the pearl shell mentioned by Captain Cook. The girdle and formless cloak have been replaced by modern clothing.

The one article of dress or ornamentation that suggests the primitive is the *pareu,* a sort of petticoat or loin cloth worn by persons of both sexes and all ages. The *pareu* is a piece of strong cotton cloth, 2 yards long, 1 yard wide, and always gaily colored. It is generally simply wound about the body from waist to knee, the two ends of the upper edge tucked or rolled under the uppermost folds, or less commonly knotted together. When riding horseback, fishing, or working in wet taro patches, or at other times when a skirt of this sort would be bothersome, a man transforms his *pareu* into a breechclout by drawing one of the lower ends between the thighs and tucking it under at the waist line behind. A man considers himself fully clothed for ordinary work when attired in a *pareu,* although generally a shirt is worn, and also trousers or overalls instead of, or in addition to, the *pareu.* A woman wears the *pareu* as a petticoat, underneath her dress, and when at home and not expecting visitors may wear no other garment. If any sleeping garment is worn, it is usually the *pareu.*

Ordinarily, men and women wear clothing made of fabrics imported by the Chinese traders. For Sundays and state occasions there are very elaborate garments: white suits for men, and for women dresses made of finer fabrics, even of silk, trimmed with embroidery and lace. Yet the man in the best tailored white suit may have his *pareu* beneath it, and certainly all the women will wear *pareu* as petticoats.

No one wears shoes except a very few people on very special occasions. I doubt that there are 20 pairs of shoes on the island.

Children are not overburdened with clothing. Babies are generally wrapped up or clothed until able to run about; from that time on until they are 7 or 8 years old it is a matter of indifference whether or not they wear anything. Girls wear simple dresses of the Mother-Hubbard type, and when

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they approach the age of puberty wear also the *pareu*. Most small boys wear only abbreviated shirts, or perhaps only *pareu* or trousers.

In this connection may be mentioned the cleanly habits of the people. From the youngest children to the oldest grandparents all regard bathing as a necessary and delightful part of the day's routine. If the house is not conveniently near a stream, the bath may be only a bucketful of water splashed over the body with the hands, but frequent trips are made even to distant streams, and in particularly hot weather or if engaged in arduous labor no limit is set to the number of trips a day. The under side of the hau leaf makes an excellent towel for scrubbing the skin and wiping off excess moisture. Soap is a luxury, but one that is greatly appreciated, especially if it is scented. Bathing in the sea is not practised except by the children, unless there is some place that is recognized as free from the filth and refuse that is generally found on the beach. An islet on the reef a mile off shore, opposite my house at Mataura is a splendid bathing place, and generally when the canoes land there in the course of a fishing trip, all hands take advantage of the opportunity for a swim. But after a bath in the salt water, or after fishing or traveling in a canoe for any purpose, a fresh water bath is always taken as soon as possible, as the salt water is believed to have a harmful effect on the skin if not washed away at once.

Other than the *monoi*, the scented coconut oil, no native perfumes are made, but any toilet preparation with an agreeable odor is very welcome. The wreaths are made of fragrant leaves or flowers, and flowers or bits of sandalwood or rosewood are placed in the box with clean clothing. This love of sweet odors is quite characteristic of the people; they detect odors that to the average foreigner are imperceptible. Much of their enjoyment of food is their appreciation of its odor, and no greater compliment can be paid than to say a person is fragrant.

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HOUSES

ANCIENT STRUCTURES

No houses in Tubuai show ancient construction or design. Hardwood poles, in a poor condition suggesting extreme age, were seen at three places. They are said to have been supporting posts for ancient houses, but are valueless as archaeological data. It seems probable that in the old days houses of any importance were erected upon stone platforms, or at least within courts more or less carefully enclosed and paved with slabs of stone. It is not now possible to distinguish between such platforms (*paepae*) and maraes without actual excavation, as with a few notable exceptions all are in very poor condition. I was compelled to observe the very letter of the French law forbidding the excavation of any archaeological sites, and was obliged to content myself with the oftentimes divergent statements of a few old people. The general opinion is that the actual house floors had not been of stone, and that there was not generally a house platform, except in places where the slope of the ground made a terrace desirable, or where a natural elevation had been selected as the house site. All informants agree, however, that enclosures were made by erecting fences of stone slabs set on edge or on end, and that for most if not all structures the space between the fence and the house itself was paved with stones, flat surface uppermost. The word *paepae* was understood and applied by the informants themselves to such courts.

MODERN DWELLINGS

In form or design, the modern houses in Tubuai are scarcely different from small houses or shacks in all parts of the world. The plans of practically all are identical—one oblong room of a size depending on the whim of the builder and the material at hand. Some of the more elaborate houses are patterned on foreign models, with two or more rooms, and are not different from ordinary small cottages. Windows are regarded as luxuries; most of them are simply openings in the walls, closed by hinged shutters of planking. Many of the houses are built of milled lumber, and have millwork sashes and doors, with glass windows.

There are several distinct types of houses, classified according to the building materials. (See Pl. IV.) All houses have the same style of roof. No particular type of roof is associated with any one wall material.

Various hardwoods, the *ati*, the *vi*, the *tuitui* are used for timber, but the hau is much more frequently used, both because of its abundance and because of its adaptability. Toa (*Casuarina*) makes excellent timber, but being too hard for ready working, is not commonly used. Planks are sometimes cut from the hau, but milled lumber is more commonly employed when

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flooring or partitions are desired. Sennit is used for permanent fastenings where nails would rust out or not provide the desired flexibility. An unidentified grass (*aretu*) is generally used to cover the earth in houses not floored with planking. In general *niau, tutuna,* and *rauoro* are used for roofing; *niau, rauoro,* and *ofe* for siding; *ofe* and *aeho* for roof "clapboards"; *haari* for sills; *purau* and acacia for poles, and posts for frame work. Galvanized iron is commonly used, but the present high cost of iron has resulted in a reversion to native materials, the hala (*Pandanus sp.*), *niau* (woven coconut leaves), and *tutuna* (a marsh grass).

The walls may be of poles, either vertical or horizontal; of staves (Pl. IV, *B*), likewise either vertically or horizontally arranged; of *niau* (Pl. IV, *A*) or lauhala applied like clapboards; of bamboo, either upright canes or split and woven in checkerboard form (Pl. IV, *D*). In connection with the lauhala, *aeho* is used to make the roofs, and, like bamboo, is set upright and bound to sills top and bottom for walls. Houses with plastered walls are fairly common (Pl. IV, *C*). They are regarded by many as nearly ideal in that they are relatively proof against rats and mosquitoes, but are undesirable because of their unquestioned dampness, and their close resemblance to ovens in hot weather.

In three plastered houses examined, the masonry was good, rough stones of convenient size being laid in a mortar of lime and sand. Kerosene cases, scraps of iron roofing, *niau,* odd bits of plank, old canoes, cut squarely across and inverted, make excellent homes for the ever-present dogs or for other domestic animals or poultry.

In Matuara, I watched the construction of the *fare auri* (jail), a well-built structure that illustrates the use of upright poles as walls, and *niau* as roofing.

The first step in construction was the erection of the skeleton walls. Poles, set firmly in the ground, about 4 feet apart and notched or forked at their upper ends, carried a horizontal plate, which rested about 5 feet above ground level, and served as the lower support of the rafters. A number of coconut trunks were roughly squared, notched to fit the upright poles, and laid on the ground outside and against the base of these poles. Upon these as sills were erected the poles forming the walls, the upper ends secured to the plate by nailing or lashing with hau bark. No attempt was made to make the structure draft-proof; the poles were merely set as closely together as their natural conformation permitted. All were reasonably straight pieces of acacia, 2.5 to 4 inches in diameter. The bark was not removed. The lower ends of the poles were secured in place by long split pieces nailed along the lower sill, one inside, the other outside, the wall, forming a groove in which the ends of the poles rested.

The roof was of the ordinary form, rising from the two longer sides of the building to a central longitudinal ridgepole. Its framework was also of acacia poles, the outer ends nailed or lashed to the plate, the inner, upper ends supporting the ridge pole and secured to it. The triangular space at each end, above the wall, and the roof itself, were of *niau,* laid clapboard fashion and nailed or lashed in place. Each end of the ridgepole was supported by a vertical pole, the lower end of which rested on

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the plate. These poles served also as support for the *niau* forming the wall at these points.

In making the *niau* coverings, fully grown leaves free from blight were selected. The leaflets on each side of the rachis were handled separately, each leaf making two mats. The weaving is of the simplest basket or checker type; the final leaflets at each end are turned back into the mat, and the only provision made against unravelling the weave is to tie one leaflet from each end together across the finished surface. When both sides of the leaf were finished, each side was split away from the central part of the rachis. The finished mats were laid aside in pairs, and thus applied to the building, the rib or upper side of the leaflet turned to the inside of the building. The *niau* for the *fare auri* were woven by a hardened sinner who had fines amounting to several days' pay, so he did not particularly exert himself to finish the job. Yet even so, a single day sufficed for him to weave over 350, the number required. He was, however, a Rurutu man, and claimed that the Rurutu people are more proficient at this art than the Tubuai people.

The earth floor was raised a few inches from the holes dug for the wall posts. It was covered with a 6-inch layer of *aretu* grass, used generally in Tubuai for the purpose. The door, made of heavy planks of hau, was swung on iron gate hinges, and secured with a chain and an enormous padlock. Incidentally it may be mentioned that the actual security of the prisoners against escape was not the house or the lock on the door, but sets of heavy leg-irons.

The plan and construction of houses made with staves or slabs set vertically (Pl. IV, *C*, in background) are not materially different from the type just described, except that the ends of the slabs in their natural state or dressed down a bit on one or on both sides, are let into grooves cut in the plates and sills of the wall frame, instead of being nailed or lashed in place. For some houses short lengths of bamboo or *aeho* are used instead of slabs, but because of their light weight a wall so made must be stiffened, with sennit or iron wire, if it can be obtained, interwoven at the mid points of the upright bamboo or *aeho*, the full length of the wall. Some walls have two or three of these cross weaves, spaced evenly. The posts or poles of the house frame are set firmly in the ground, and a heavy sill laid against them as base for the upright sticks of the wall.

The bamboo house most in favor is that with woven walls (Pl. IV, A). The customary skeleton framework is raised, and perhaps roofed, before the walls are completed. Long bamboos, split in a sufficient number of pieces to lie fairly flat when opened out, are woven in plain checker pattern. If a particularly strong and weather-proof house is desired, the walls are made double. In Tubuai the objection to this type of house is that insects that eat the bamboo create a fine dust and eventually destroy the house.

A plastered house may have walls of poles laid horizontally, plastered outside and in, or walls filled in, between the poles, with a wickerwork of lighter or split poles, upon which the plaster is smeared. The floor of the plastered house may be simply earth, covered with a layer of *aretu*, or it

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may be loosely laid sand and gravel, with plaster spread evenly on top. Such a floor is regarded as cold and hard.

Lauhala roofs are regarded as best because they are more durable even than iron roofs and also because they make for coolness.

Dry leaves of the wild *Pandanus* (*rauoro*)—not the cultivated variety used for mat and hat making—are selected, broad leaves over 5 feet long being preferred. These leaves are folded over at a point about 1 foot from the butt end, and strung along on a stalk of *aeho*. Each leaf slightly overlaps the preceding one, and all are held in place by a splinter of bamboo (*ohe*) or a slender twig of *moomoo*, threaded skewer-like through both long and short sections of successive leaves, about 6 inches from the fold. About 24 leaves are required to make a single "clapboard," about 52 inches long. The effective width of the clapboard is about 1 foot, the length of the heavier part of the leaf, but the extra length of the tapering ends, which form always the upper surface of the clapboard when in place on the roof, adds quite materially to the durability and servicability of the roof. It is said that the butt ends of the *Pandanus* leaf rot quite readily if exposed to the weather, but that the other end stands years of exposure.

The ridge of the roof made of lauhala, *niau*, or *tutuna*, is protected by extra heavy covering. After the sides of the roof are completed up to the ridge, one or more layers of banana leaf are laid with the mid line of the leaves along the ridgepole. Part of the midrib is cut away to lessen the bulk. In some houses firmly woven *niau* replace banana leaves; in others no foundation layers are used. A thick layer of marsh grass (*tutuna*) is placed over these foundation layers, the ends of the leaves hanging equally on either side of the ridge. Heavy poles, laid parallel to the ridge and about a foot from it, hold the grass in place. These poles are secured either by strips of hau bark, or by forked sticks, tied in pairs, straddling the ridge and holding the poles in their forks.

In two bamboo houses observed, one end was half round. The sills were cut so as to lie in a semicircle; the upright supports set a trifle closer together than in houses with square ends. The roof of the semicircular section came to a point at the end of the ridge of the straight sides of the roof. I was informed that formerly many houses were so made, or made with both ends round. No one remembered seeing or hearing of houses with circular or oval floor plan.

For a cookhouse a "lean-to," a small house of the ordinary type is built. (See Pl. IV, *C*.) The cookhouse of a wealthy family may be as elaborate as the dwelling of an ordinary family and when new dwellings are built, the old one may serve as cookhouse. The distinguishing feature of a cookhouse is a space left clear of flooring and generally fenced off from the rest of the floor by a timber or two. The fireplace is at best merely a few fire-tested stones of convenient size, set in a bed of ashes. No smoke vent is provided.

BUILDINGS FOR SPECIAL PURPOSES

Public meeting houses in villages on various of the islands are mentioned in various early accounts. The site of one such house, in Mataura, is still clearly remembered; the sheltering structure existed until late in

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the nineteenth century. The modern *himine* house, in which the people meet for church song services, differs from the ancient structure only in size and the use of iron instead of lauhala or coconut leaf for roofing. It consists of a rectangular space, enclosed within a knee-high wall known as the *aua-moa* (chicken barrier), and protected from the weather by a roof, supported on a framework of poles set about the edges of the enclosure. Of several such structures on the island, the one at Mataura is the largest, accommodating 400 people. The ancient structure is said to have been three times as large.

The eight churches in Tubuai with various subsidiary structures, are entirely modern in design and construction. At least one of the buildings, that erected for the Church of Jesus Christ of Latter Day Saints at Huahine, Tubuai, has used stones from maraes in its construction.

There are no elaborately made canoe houses in Tubuai. A few shed-like structures, consisting of coconut leaf or lauhala roofs supported on skeleton frameworks of poles are in use.

The French Government maintains a few buildings for official use. All of them except the recently constructed jail are modern in design, construction, and material.

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TRANSPORTATION

Tubuai differs from many neighboring islands in the absence of any barrier to easy passage along the beach. It is possible to walk entirely around the island in a few hours. A good road follows the shore line; a second road crosses the island from north to south (Pl. I). Riding horses, pack horses, and carts are available for travel.

Most of the trails are impracticable for carts or even horses. Over these travel is necessarily on foot, the burdens being carried by men in primitive fashion—in the hand, at the ends of a pole, supported on the bearer's shoulder, or swung from the center of a pole borne by two men. The Tubuai man does not employ the shuffling jog-trot of the Chinese coolie, designed to take advantage of the springiness of his pole; he carries his burden by sheer strength and endurance—qualities remarkably developed. I have seen sailors carrying three thirty-kilogram sacks of copra at a time, trip after trip, from the shed a hundred yards inland to the ship's boat, lying in waist-deep water a hundred yards offshore. To facilitate carrying, small objects may be placed in bunches: coconuts are tied together, four in a bunch, by strips partially torn from the husks; taro is tied in bunches like green onions in American markets. Women frequently carry heavy loads, but men are commonly the burden bearers.

Every man in Tubuai owns or has an interest in a canoe. Little use is made of them as freight carriers: transportation by land is too simple a matter. Naturally, therefore, the canoe has been developed to serve the needs of the fishermen, and most canoes are built for the use of only one or two men. Some, however, are capable of carrying six or eight persons, or an equivalent amount of cargo. These are generally provided with sails. Tubuai canoes are paddled or sailed, never poled along like the Raivavaen canoe.

There are historical and traditional accounts of voyages to Rurutu, Tahiti, Raivavae and to other islands, presumably in canoes larger and more seaworthy than those now in use.

Of these ancient canoes no remains were found and the description of them in the literature is meager. (See 15, vol. 1, p. 53; vol. 2, p. 6.) The concensus of opinion in Tubuai is that they were *va'a* (canoes) in design and construction somewhat different from the modern canoe, but not *pahi* (ships) like the double canoes of the Tuamotuans.

Rafts are not now in use, and I was unable to learn anything definite about those of earlier times. I was told that at some indefinite time several generations in the past, a certain man captured a turtle, and neglected to give it to his chief, to whom it was rightfully due. The offended chief banished the man and all his family. The people, to the number of eight or

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more, were placed on a raft (*paepae*) and towed out to sea by the chief's canoes. They were given a small amount of food and water, and, when out of sight of land, cast adrift. The raft eventually landed at Rurutu, with some of the people still alive. A woman now living in Rurutu is said to be descended from them.

My experience shows that the men of modern Tubuai cannot be ranked highly as sailors. They are excellent canoe men, fair sailors, but poor navigators. In handling the outrigger canoe, at the paddle, or when sailing the tiny craft, they are hardly to be surpassed. In all the years that memory can recall or tradition record, only four Tubuai men have met their deaths in canoe accidents. Three of the accidents were due to recklessness; the fourth was presumably due to the weakness of the victim, who was too ill to handle his canoe in a storm. When it is remembered that most of the men of Tubuai go fishing several times a week, and many sail their canoes several miles outside the barrier reef, this record is strong evidence of their ability to handle canoes.

Many of the canoes are rigged with sails, like the ordinary sailing canoe or cutter, and with these the fishermen venture some miles from land, if the weather is not threatening. In sailing these canoes the men are quite expert but never undertake long journeys in them. I was not able to persuade anyone to take me to Raivavae, only 90 miles away.

In the handling of larger craft the men are less expert. The locally owned schooner, now taken over by a Tahiti trading company, was a fast boat, and under favorable conditions made very quick trips between the islands. Her record for the trip to Tahiti is less than 4 days, which is considered excellent time, and to Rurutu and to Raivavae less than 24 hours. On the other hand, I made a trip on her from Tubuai to Raivavae which took 8 days actual sailing time. The slowness was entirely due to poor seamanship. In rough weather or heavy seas the sailors prefer to carry the minimum of sail, rather than to take advantage of the wind and risk a little canvas. I have seen all hands come below, during a storm, and hold a prayer service, when a crew of Gloucester fishermen would have been on deck, with at least some of the sails set, making the wind serve them instead of letting it drive them as it pleased.

Some remnants of old time navigation lore persist, but I was unable to get any accurate knowledge of it. The navigator will spend hours watching the water, noting color, apparent direction of currents, and the amount of leeway the ship is making. He watches for birds, for peculiar cloud formations, for color of sky and odors on the wind. I was told that all of these factors were important and that experience alone could tell one how to interpret them. Stick charts or charts of any sort other than those furnished

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by the French Government were unknown in Tubuai. Every captain has a copy of Bowditch, a Nautical Almanac, and a sextant, all of which are required by law. But the Bowditch is generally decidedly the worse for wear, the Almanac is seldom up to date, and the sextant is, to say the least, not absolutely correct. One, I remember, was so badly out of adjustment that the schooner passed to the east of Tahiti instead of to the west, as the captain had intended! Chronometers are exceptional and dependence is generally placed on ordinary alarm clocks. Of course there is a compass, but one captain confided in me that his compass was erratic, and that he frequently pointed his schooner toward the port he intended to reach without reference to the compass. So far as I could determine, his compass was quite dependable. My conclusion was that the captain preferred to trust his instinct or whatever it is that guides the born seaman, rather than his knowledge of scientific navigation.

In connection with navigation, and later in investigating other topics, I attempted to list the native names of the stars. To my surprise, I found no one able to give me names for anything but the sun, the moon, and the Pleiades. For sun, the word *mahana* is in common use, but the older word, *ra,* is understood and occurs in compounds, in place names, and personal names. Similarly the word for moon is generally *avae,* with *marama* recognized but obsolete. The word for the Pleiades, as elsewhere in Polynesia, is *matari'i.* In a chanted tale, two stars are collectively known as Pipirima or Pipinima, less commonly as Ainauu (p. 373). It has been suggested that the name has been applied to two heavenly bodies which at times appear close together, but at other times are separated. This would account for the fact that, although several people confidently attempted to point out Pipinima, no one succeeded in positively identifying them.

The people of Tubuai are familiar with many of the star names given by Jaussen (27) and by the London Missionary Society (17), but were not able to define them accurately.

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FISHING

FISH SPEARING

Two methods of fishing prevail in Tubuai: spearing, done by the younger men, and hand line fishing, preferred by the older men, who fish from canoes. Fish nets are little used. The following description may serve to illustrate the methods employed in fish spearing:

One morning six of us set out in a large canoe for a well-known nearby fishing ground. There were six spears at hand in the canoe: (No canoe is considered "well found" unless at least one spear is provided.) We paddled to a place a hundred yards inshore from the barrier reef, where mushroom-shaped patches of coral rose to within from 5 to 2 feet of the surface. The lagoon was there about 12 feet deep. We stopped a few yards away from one of the coral patches, and two of the men, taking with them their spears, slipped overboard and swam toward it. Two others, with their spears, swam toward a coral clump somewhat farther away. Swimming slowly, face down in the water, they watched for fish hiding near the coral. Suddenly one of the two nearest the canoe called to his companion, and both "sounded." Down they went, one on each side of the coral clump, but the one fish large enough to be worth while escaped, and headed for the neighboring clump, near which the second pair of spearsmen were swimming. The first pair rose to the surface, and called to the others, telling them that a large *i'a tia* (parrot fish) had escaped in their direction. Down went the second pair, and with better fortune, for one rose almost at once and shouted to us in the canoe to bring another spear. Before we were able to do this, his companion had come up, been directed, and had "sounded," emerging shortly with the fish and both spears. The fish measured a little more than 2 feet long, and was quite heavy. The first man had thrust the point of his spear completely through its body, but had released his hold and allowed the fish to swim away, hampered by the spear. My companion told me that such procedure was quite customary when large fish are speared, as there is greater danger of breaking the spear than of losing it together with the fish. The wounded fish never swims far: a spear is almost never lost. Presently the first pair of swimmers were successful, accounting for several of a school of smaller fish. We then proceeded to some other coral clumps, farther along the reef. The swimmers came aboard, and all paddled. Incidentally, none of us was particularly hampered by clothing, wearing only the *pareu* tied breech-clout fashion. At the new grounds the same tactics were repeated with indifferent success, but at the end of a couple of hours there were enough fish in the canoe for all of us and for some of the neighbors.

In swimming, before sounding, the fisherman holds his spear by the extreme tip, generally in his left hand. When going into action, the spear is shifted to whatever position the man favors: it may be grasped by the middle with the right hand and simply poked at the fish, or held similarly with the arm extended, the thrust accomplished almost as much by the forward motion of the swimmer's body as by his arm motion. All the possible ways in which a spear thrust can be made seem to be used as occasion demands. The men develop astonishing ability to recognize fish in the water, and to calculate their speed and probable direction. Their accuracy of aim is amazing; to me, after trying the game, nothing short of incredible.

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The length of time actually spent under water varies; the average time was about 65 seconds. I have been told on good authority that few can exceed that time, but that some exceptional fishermen, like the pearl divers, can remain under water about two minutes.

An indispensable part of the equipment for spear fishing is a pair of goggles. Most of those used on Tubuai are homemade, of sheet copper or brass, with lights made of ordinary window glass, painstakingly cut to fit the frames. The goggles fit closely over the eyes, and while they do not exclude all the water, they give the wearer clearer vision.

The spear has a straight, tapering iron point without barbs, 10 inches to 2 feet long, and from ¼ to ½ inch thick at the base. It is set into the end of a stout, light pole, the dimensions of which depend on the use to which the spear is to be put, and the personal preference of the owner. The end of the shaft into which the point is set is strengthened by an even wrapping of wire or sennit. Hau is the most favored wood for the shaft.

It seems probable that this method of spear fishing witnessed by me originated elsewhere than in Tubuai. The natives declare it of recent introduction from the Tuamotu Islands, and in support of their claim state that older men seldom practice it. During a brief visit to the Tuamotus I found the method used very generally except in places where sharks were dreaded, and was told by the natives that the method originated with them.

A simpler method of spear-fishing is quite common in Tubuai, and is said to be the old-time method. The fisherman, armed with the sort of spear just described, and trailing from his waist or shoulder a strip of hau bark on which to string his fish, walks along the barrier reef or along the coral in the shallow water near shore. The fish hide between and under the branching coral knobs, and are sometimes hard to find, but a few hours' work generally yields a satisfactory supply, as a good fisherman rarely misses his thrust. This simple method is elaborated by mounting the spearman in the bow of a canoe, with a second man at the paddle. The canoe is driven slowly along the edge of the coral formation, within the lagoon, or, if the tide is full, over the tops of such parts of the inner reef as are submerged. Either of these two methods may be used at night by providing torches. The material used for the torch is the palm spathe, with dry leaves of the palm, all bound tightly together in a bundle from 6 to 10 feet in length and 8 to 16 inches in diameter. Such a torch gives a bright light, and will burn for an hour or more. Several torches are prepared in advance and either left at a convenient place on shore or stowed in the canoe, if one is used. Strings of kukui (*tuitui*) nuts are sometimes included with the other material bound together for torches.

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HAND LINE FISHING

Hand line fishing is done almost entirely with commercial tackle, consisting of hooks Nos. 5, 6 and 7, with correspondingly light lines. Smaller hooks and lighter lines are used for casting. Some hooks are made from a nail or a bit of copper, iron, or steel; and for certain forms of fishing, shell and wooden hooks are used. A fisherman goes out for some particular variety of fish, and is equipped accordingly. This sort of tackle is used in the lagoon and in the relatively shallow waters just outside the barrier reef. For deep sea fishing heavier hooks are used, and for certain varieties of fish found only at distances of one or two miles from shore, the wooden hook (Pl. V, *A*) is used. The shell hook is used only for trolling, and is generally trailed behind an incoming or outgoing schooner, as the particular fish taken with it frequent the passes through the reef or the channels between the islands. Occasionally, a lure is prepared by tying white feathers on the shank of an ordinary hook. This hook is used in night trolling with a sail canoe or an ordinary canoe with two or more paddlers. A brief description of personal experiences will illustrate the method of hand line fishing:

My canoe was used, as I had an outboard motor whose labor-saving advantages my companion readily acknowledged. The canoe had also its regular sail, paddles, spears, and bailer. My companion and instructor was a middle-aged man recognized as a skilled fisherman. He provided the fishing equipment, which included a handful of medium-sized hooks (No. 6), a hundred fathoms of medium-weight line, bits of lead for sinkers, a stout knife, and bait of two sorts: a black, putty-like substance, made of taro scrapings mixed with the viscera of squid, and the flesh of the squid. My companion explained that some fish favored the taro mixture, other preferred the flesh of the squid. Small bits of each kind of bait were strewn overboard as we approached the fishing ground, to serve as lure. I thought best to stop the engine, when we had nearly reached the fishing ground, lest the noise of the exhaust frighten away the fish. My companion ridiculed the idea, and with one of the paddles as club began striking the sides of the canoe, to made additional noise. At the same time he called, in all seriousness, "Mai, mai, mai! (Here! here! here!)," many times, as though calling chickens, and from time to time strewed more of the bait on the surface of the lagoon. The noise, he explained, was to rouse the curiosity of the fish; the lure, their food, to make them unsuspicious, so that they would more readily take the baited hooks!

After the anchor was dropped, no time was lost in getting the hooks baited and overboard. By this time a number of small fish could be seen, a few feet below the surface, nibbling at or bolting the food. But they refused the baited hooks; only a very few could be enticed to even nibble. My companion assured me that the fish were temperamental and that for some reason they were not properly playing the game. Generally, he said, the tactics we pursued would result in an excellent catch. We did manage, after trying several different places, to land a few small fish. My companion was disgusted, and could not appreciate my satisfaction with the performance.

On another occasion, however, when a three-hour wait at the fishing grounds was rewarded by the capture of a single fish, my companion was well pleased. The fish, an *oi'o*, in appearance like the mackerel, was one very highly prized, and was large enough to serve even a Tubuai family. It was taken with a hand line, but with a barbless,

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homemade copper hook baited with a bit of squid tentacle. My companion had stripped the tough skin from the tentacle with his teeth, biting it into small pieces. These bits of skin he had dropped overboard as lure. The *oi'o* is a very wary fish, and consequently we cast our baited hooks, weighted with sinkers, as far as possible from the canoe in the direction of the tide.

A man fishing for *oi'o* will never try simultaneously for any other sort of fish, but will cast two lines, then wait for hours, rebaiting his hooks when necessary. He will be pleased if he secures one fair-sized fish, and entirely satisfied with two or three, even though he may have spent the entire day catching them.

NET FISHING

Hand Nets

Commercial nets and net twine are too expensive, and the preparation and knotting of native materials too tedious and laborious for nets to compete with spears or with hooks and lines in fishing. Only two hand nets are in use in Tubuai, both of them were brought from Tahiti. It is certain, however, that in former times the art of net making was well known, and that nets were in general use.

The Rau Ere

The name *rau ere* is given to a sort of drag-net made of *niau,* and used in relatively shallow water. The length may be as great as one mile; of three observed, the longest was slightly over one-half mile. The length depends of course upon the number of persons expected to take part in the operation. On one occasion I saw 85; on a second occasion 100 people taking part, and I have been informed that as many as 200 people may serve a single net. From my note book the following is taken:

On Monday of this week the word was circulated that the people of Mataura would make a *rau ere,* to be used on Wednesday and succeeding days. On Tuesday all those who could conveniently leave other work went to Tamatoa, the place best suited for the fishing, to make the *rau ere*. This work occupied the time of perhaps 30 people for a day and a half, and was completed Wednesday shortly after midday.

The leaves of the cocopalm (*niau*) were cut and sorted roughly for length. The leaves were cut from any palms, but preferably from those not paying ground rent in their yield of nuts. The second step in the operation was the splitting out of the rachis, or midribs, only enough being left to hold the leaflets together. These sections were then laid end to end overlapping 6 to 8 inches, and with the leaflets all on the same side of the midrib. The sections were laid thus, three in a row, and eight or nine deep, the butts of the *niau* sections in one layer resting on the tips of the sections directly below, so that the inclination of the leaflets alternated. Each section was then tied to the one next in line at the overlap. Hau bark served as cord. The layers were bound together at the ends by a tie of hau bark about the ends of the midribs; a stout strip of hau bark extended the length of the pile along the midribs, and was secured with them at each end. This served to reinforce the relatively weak midribs. The

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completed pile was then twisted into a sort of rope, one man grasping each end, assisted by one or two others in between. The twist was made as tight as the strength of the operators permitted, from six to ten complete turns being given the pile. This completed portion was united to similar portions by winding together the adjacent ends and binding firmly with hau bark. The length of the completed *rau ere* was nearly 3,000 feet.

All the men and some of the women next provided themselves with stout poles 10 to 14 feet long, one to each person who expected to get out into water too deep for standing. A large canoe was provided for the captain of the day, and carried besides its usual complement of paddles and fish-spears, a very ancient and much patched scoop net, the capacity of which was about 20 fish of average size.

Tamatoa was selected as the place for the *rau ere* because of the nature of the beach. Here the lagoon is shallow for the greater part of the distance (about one and one-half miles) to the reef, and there is no inner reef or outcropping of rock near shore. Half a mile off shore, in 10 feet of water, there are a number of rocks, but even these do not come within 6 or 7 feet of the surface. Moreover, these are the recognized haunts of some of the most desirable fish.

When all except the inevitable belated few had assembled at the beach, the men acting as captain made a brief prayer, calling for good fortune in locating the largest possible number of fish, and for physical strengthening of the bodies of all taking part in the labor. Next came a few instructions, and a distribution of the forces. Certain of the most powerful and experienced men were placed at the forward end; the men and the more daring of the women next in line, and finally the women and the children of both sexes. Young children did not take part. I took my place near the forward end, being careful to select as my nearest companion a friendly young giant nearly 7 feet tall, who proceeded to coach me in the use of the pole.

The *rau ere* was first dragged into the water, parallel with the shore, until it floated clear of the bottom. Then the forward end was towed out until the line was at right angles to the shore, and then straight on out until the women on the shore end had about reached their depth. The forward operators were all in water 5 to 12 feet deep, and were advancing with the help of the poles. At about this time the canoe came along, and I climbed aboard, to get an idea of the extent and general appearance of the operation. We paddled from end to end of the line, the captain calling on certain stronger operators to move nearer certain of the weaker, so that the strength of the force should be fairly evenly distributed. I then returned to my place in line, or rather to a new place to fill a gap caused by one operator dropping out, and tried again to master the art of poling myself along. The operation may be compared to wading in deep water with a single stilt, one's body immersed to the chin, incidentally, of course, dragging the *rau ere* along by means of a thong of hau bark passed over the shoulder. But unlike a stilt, there is no step on the pole: the native grasps it with his foot, the pole between the great toe and the next adjacent. The point at which the pole is grasped by the foot depends of course on the depth of the water. The operation looks quite simple, but after nearly three hours of it I declared it hard labor.

When the first of the operators not provided with poles reached her depth, the forward movement of the line halted, and both ends moved quarteringly, the forward end toward, the other end away from, the shore. The midsection held fast, so that the line assumed a crescent shape, the outer end first partly encircling, then passing on over the submerged rocks already mentioned. When the line had assumed a U-shape, the midsection slowly gave ground shoreward, the shore end stood fast, and the forward end moved to meet the shore end.

When the circle was completed, the leaders doubled back along the outside of the enclosure, and the operators at the other end did likewise. The operators followed their leaders, taking care to keep the lessening circle closed. The two ends of the line

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met again at a point opposite the mouth of the circle, and again doubled back. When they once more met, at the original meeting place, the formation was declared perfect. The circle then had a complete triple wall, of operators holding the *rau ere*, and was about 300 feet in diameter. The circle was next flattened into an egg-shape, the narrow end toward shore. This end was pinched together, gradually lessening the enclosed space until there remained only an oval some 8 feet wide and 35 feet long. All the operators now stood in about three feet of water, so that the ends of the *niau* leaflets dragged on the bottom. Two operators now took the scoop net, and walked from end to end of the enclosed space, emptying the net each time into the canoe. When at length it was fairly certain that few if any fish had escaped the net, the captain called to the leaders to unwind their net, and go out once again, to repeat the entire operation.

Enough time was taken then, however, to enjoy the solace of cigarettes and of drinking coconuts. Some of the operators had left their places at the finish, and gone on ashore, returning with tobacco, *Pandanus* leaves, and two or three chunks of burning wood, also with a supply of coconuts for the thirsty.

The entire operation was now repeated, from the distribution of the forces to the scooping up of the fish. This time, however, when the fish had been bailed into the canoe, the captain called on his leaders to unwind and head for shore. The *rau ere* was spread along the beach above high water mark, and the work of distributing the fish was undertaken. Some slight preference was shown the leaders in the work, but otherwise it was an even division. The share of my household, two members of which had taken part, was two excellent fish and a large portion of an exceptionally desirable one. It may be noted here that some fish, less common and more desirable, are generally cut in portions so all may have a bit. Incidentally no count is made of the large number of small fish not caught in the net, but in the hands of the operators.

A second *rau ere* was attended about a month later. The following notes resulted:

The actual length of the *rau ere* today was 3,600 feet, most of which has served for nearly a month; the weaker sections were reinforced with wrapping and ties of hau bark; some sections too frayed or worn to be trusted were cut out and replaced. In addition to the new parts used as patches about 300 feet of newly made net was added at the forward end.

The *rau ere* was drawn twice today. This is nowadays the regular thing, though in the old days it is said that once sufficed to provide all comers with plenty of fish. This statement tallies with many similar ones to the effect that fish were formerly far more plentiful than at present. The first trial today resulted in only two fish being taken, after at least two hours of dragging the *rau ere* through the water. The 52 persons who took part, included the master of ceremonies, who patrolled the line in a canoe, and myself, acting as motive power in the canoe and attempting photographs. After the first disheartening haul, many quit and went ashore, but the majority decided on a second haul, which resulted more fortunately. The net result of the day's labor was two cuts of fish a person. The larger fish, the *oʻo*, related to the tuna, were cut in three sections, the smaller ones, those 16 to 24 inches or so in length, were cut into two. The results were regarded as satisfactory, though not such as to cause exuberant rejoicing. In this connection may be repeated the story of one historic occasion: The *rau ere* was drawn in just that same place, and at about the same time of day, from 4:00 p. m. until about 7:30 p. m. About the same number of people took part, and the same man was master of ceremonies. Instead of a canoe, a ship's boat served as his vehicle and to receive the fish. The number of fish was so great that the boat was on the point of sinking. To avoid losing all, the remaining fish were abandoned, and the boat taken ashore. The share for each person, including as persons

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even the small children who had come out at the finish of the labor as spectators only, was about 20 fish. This is the mildest version of the story; other informants stated that many fish were left on the shore by those to whom they were distributed, as it was not worth while carrying home more than the families and their neighbors could consume. Another version of the story is that the boat in which the fish were loaded belonged to a Rurutu schooner then in port. The boat took one full load to the schooner, the fish being subsequently salted and dried, and taken to Rurutu; after delivering the boat-load to the schooner, the boat returned to the *rau ere* and took ashore enough fish to more than satisfy all those present. Still other versions soar beyond the limits to which even a fish story may aspire. It is certain, at any rate, that upon some former occasions vastly greater hauls have been made than those I have seen.

The making of a new section of the *rau ere* was watched, and a point noted overlooked before. The halves of the *niau* are always so laid that the midrib of the leaflet is uppermost (this in the "pile" of *niau*, arranged before being twisted into the finished form). Less regularity is observed about placing the halves alternately butt-foremost and tip-foremost, though this is nearly enough the rule to insure fairly uniform bushiness of the completed *rau ere*.

There were very few people in proportion to the length of the *rau ere* today, and consequently a different system of getting it into the water was necessary. A series of coils was made, with perhaps six fathoms in each coil, and four or five fathoms between coils. In this form the *rau ere* was dragged out until it extended in a straight line out from shore. The coils were then loosed, and the *rau ere* extended its full length. It was necessary, however, for the man in the canoe to exercise great vigilance to prevent the *rau ere* being parted when a submerged section became tangled (*fifi*) on an obstructing coral knob, as it frequently did. On such occasions the men in the canoe would attempt to disentangle the *rau ere*, using a long pole for the purpose, and if unsuccessful would call to the nearest person in the water to dive down and free the line. On one such occasion, when the bottom was obstructed by a number of very bad knobs, the canoe acted as float or buoy for the *rau ere* until the dangerous place was passed by. Had there been a larger number of people present this of course would not have been necessary. As it was, there were intervals of over 100 feet between operators.

After the *rau ere* came the division of the fish. Those who took part in the work were counted, the fish sorted as to kind and size, counted, and the division made as fairly as possible. The attempt was made to allot to each household at least one cut of the *oʻo*, the most highly regarded of the local fish, and to see that the less desirable fish were evenly distributed. This work was excellently done. Not one word of comment was to be heard as to partiality or unfairness. The time consumed, however, was enormously prolonged by discussion of the relative value of the various fish, before the actual cutting up and dividing.

Incidental to the *rau ere* there is considerable gaiety, and on the past two occasions some provident person has seen to it that a liberal supply of banana liquor (*ava meia*) was on hand. As a result there were several persons somewhat exhilarated each time, and a strict censor would have found himself hopelessly swamped by the indiscretions, near-indiscretions, and super-indiscretions committed. In all fairness, however, it must be said that the majority of the people were at most interested spectators or eavesdroppers, and the remaining few were either case-hardened sinners or young folk with no definite domestic ties to limit their freedom.

Subsequent to the two fishing trips described, similar affairs were attended, but no new details noted. Mr. Doom told me that every few years some one suggests making a *rau ere*, and for a few months the net is drawn

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frequently; then the people tire of it, and for several years none is made. In former times the *rau ere* was much more used.

In an economic sense it hardly pays. It entails the best part of a day and a half in preparation, then half a day every time the *rau ere* is used. One *rau ere* will last, with reasonable luck, five or six weeks. But sometimes a drag is made, and few or no fish taken; at best not more than four or five for each person engaged can be hoped for. One man, in his canoe, with reasonable luck, can catch that many fish each half day. However, the occasion is always a festive one, and greatly enjoyed even if the material results are not great.

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WOOD WORKING

TOOLS AND THEIR USE

The modern woodworking tools of Tubuai are the same as those used in any community where only rough carpentry is required. Saws, axes, adzes, hammers, chisels, planes, drills, and augers are to be had whenever the work in hand requires their use; each man has at least the essential tools, and can readily borrow what he lacks. Each artisan has special tools so that almost any sort of rough carpentry or cabinet work can be done.

Besides house and canoe building, woodworking includes the manufacture of wooden bowls for various purposes, ranging in size from small, shallow platters used for table purposes, to long canoe-shaped troughs used for making manioc starch; coconut grating stools (p. 39) and various household and farm appliances such as stirring paddles for use in cooking, handles and hafts for tools, and repair parts for road carts. The utmost skill is shown in the use of the ax and the adz. The canoe-maker cuts with full-arm swings, each stroke, striking fair and exactly as intended, so that the surface when roughed to shape needs very little trimming to remove tool marks before final polishing.

I watched a canoe-maker shaping a hull; not once did his tool slip; not once did it cut past the line; calipers showed a uniformity of thickness in the finished hull that could scarcely have been surpassed by machine work.

Ornamentation plays no part in the modern woodworking craft. No trace can be found of the elaborately carved canoes mentioned by early voyagers. The bowls, called *umete* (Pl. VI, *A*), have each a lip at one end, and a double or trebly terraced boss at the other, but otherwise they are plain. House posts and sills, and in fact all the woodwork of the houses, is likewise quite plain, and, in most cases where native materials are used, the woodwork is only roughly hewn.

Few examples of ornamental woodworking are to be found in Tubuai. I was fortunate in procuring tapa mallets, spears, and sections of house timbers.

The tapa mallets, all of toa (*Casuarina*), are well made, with handles of convenient shape, and the four faces of each implement scored with 2 to 60 clean-cut parallel longitudinal lines (Pl. VII). Three mallets have one face on which the lines are diagonal in both directions, forming crosshatching. I am indebted to Mr. John F. G. Stokes for the following descriptions:

The 31 mallets range in length from 350 to 450 mm., and in width from 35 to 55 mm. The grip is one-third to one-fourth of the length of the mallet, and is circular or subcircular in cross section. In one-third of the mallets, the sides of the grip are roughly parallel; in two-thirds they are constricted in the middle and flare towards the top gradually or sharply as shown in Plate VII, *B*, 2, 3; *C*, 3. The body of the mallet

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is almost rectangular in cross section. In most specimens, the transition between the grip and the body is gradual (Pl. VII, *A*, 5; *C*, 3). In ten of the specimens the transition is marked by a shoulder (Pl. VII, *A*, 3, 7), or by an abrupt change from circular to rectangular cross section (Pl. VII, *A*, 2).

The faces of the mallets are plane or slightly convex, and meet in well-defined angles. Those of each mallet are approximately equal, though one mallet bears faces 37 and 45 mm. in width. The margins are approximately parallel, but two-thirds of the mallets show a slight decrease in width toward the grip, one-sixth are widest in the middle, and the margins of the remaining one-sixth are parallel or diverge slightly towards the grip.

The faces of 27 of the 31 mallets are incised with longitudinal parallel lines. The lines of each face are set at fairly regular intervals but on different faces ranging from 15 to 0.7 mm. apart. The widely separated grooves are broad and deep in the middle, and narrow towards each end. For example, those shown in Plate VII, *A*, 1 are 3 mm. deep and 7 mm. wide.

None of the mallets shows all faces similarly grooved. Half of them carry two types of faces. Nearly half, three types; and a few have four unlike faces. The similar faces are generally but not always opposed. Though the grouping of the mallet faces is not quite regular, it is of interest to note that most of the mallets fall into two groups, in one of which the coarse groovings are combined with the medium, and in the other the medium with the fine. The combination of coarse and fine grooving is absent. The faces of a very few mallets are all finely grooved. It is evident that a tapa-maker's kit should contain at least two mallets, one with wide grooving for the initial work and one with the fine groovings for finishing.

Four mallets are exceptions to the prevailing type characterized by parallel grooving on all four faces. One of them (Pl. VII, *A*, 1), an implement probably used for initial work only, has two plain and two coarsely grooved faces. The other three (Pl. VII, *B*) show each with one face marked with lozenges in relief, carefully made with diagonal lines or channels, and the remaining faces incised with fine or medium fine grooves. This lozenge design was evidently intended for finishing, like the Hawaiian mallets which left a "water-mark" in the fabric in the final beating.

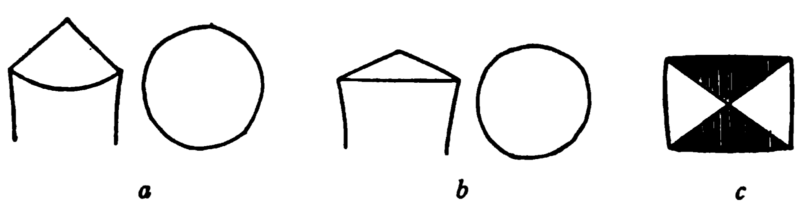

FIGURE 1.—Sketch showing ends of Tubuai tapa mallets: *a*, *b*, ends of grip (B. 4659; B. 4657); *c*, end of body of mallet (B. 4669a.)

The ends of most of the mallets are transverse planes, some of which have been cut by steel tools. However, in a few mallets the grip terminates in a flattened cone or a pyramid (fig. 1), and the body terminates in a low pyramid. The body of the mallet shown in Plate VII, *C*, 2 ends in an ornament consisting of quadrants, the upper and lower of which have been cut about 2 mm. below the level of the others (fig. 1. *c*). This may be an ownership mark, as the diagonal cross appears in light incisions on other mallets.

It is possible that some of the mallets described did not originate in Tubuai. They are very similar to mallets collected elsewhere in the Austral Islands and also in the leeward Society Islands. The dimensions and groovings of the mallets shown in Plate VII are tabulated as follows, the measurements are in millimeters:

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PLATE VII	LENGTH	AREA OF FACE	WIDTH OF GROOVES ON FACES	MUSEUM NUMBER
A, 1	368	234 x 49	15; 2.1; 12; 2.2	B. 4665
A, 2	373	239 x 42	7; 2.2; 8; 1.8	B. 4646
A, 3	363	237 x 44	5.4; 11; 5.4; 11	B. 4645
A, 4	434	297 x 53	3.4; 1.8; 2; 1.9	B. 4658
A, 5	409	273 x 43	1.9; 10; 2.8; 10	B. 4640
A, 6	434	282 x 51	1.5; 2.9; 1.4; lozenge	B. 4668
A, 7	361	247 x 48	plain; 11; plain; 11	B. 4648
B, 1	432	304 x 42	lozenge; 1.9; 1; 1.4	B. 4667
B, 2	421	309 x 54	lozenge; 1.7; 1.3; 3.5	B. 4669
B, 3	434	282 x 51	lozenge; 1.5; 2.9; 1.4	B. 4668
C, 1	365	245 x 44	10; 4.6; 11; 4.4	B. 4642
C, 2	390	285 x 37	4.2; 2; 2.2; 4.2	B. 4669a
C, 3	428	309 x 49	2.6; 1.6; 0.7; 0.9	B. 4657

The spear is a straight shaft of hardwood, 6 feet, 5 inches long, with octagonal cross section from the base to a point 17 inches from the tip, where it becomes nearly circular by a double boss, encircling the shaft 9 3/16 inches from the tip. The head of the spear is separated from the shaft proper (Pl. VI, *C*). At the boss, the diameter of the shaft is 1 3/15 inches; 13 inches below it increases to 1⅛ inches and retains that diameter 15 inches; then tapers gradually to a blunt terminal point. Above the boss the greatest diameter is 1 3/16 inches. Originally the spear was slightly longer and the points somewhat sharper. There is no ornamentation. The workmanship on the spear is excellent; its lines are true and its balance perfect. Close examination shows marks of the rather dull tools in the angle between the shaft and the boss.

The fragment of worked toa (*Casuarina*) wood shown in Plate VI, *B* is a part of weapon or implement the use of which is now forgotten. The old woman from whom I procured this specimen told me that it had been around the place ever since she could remember, and that as a child she had been told that it was a piece of an ancient spear. One side of the blade blends smoothly into the shaft. The opposite side is marked off from the shaft by a shoulder, below which the shaft is carved with five transverse grooves in herringbone pattern. The width of this ornamented strip is 1 2/10 inches and the carving appears only on the surface corresponding to the upper side of the blade.

The sections of carved planking shown in Plate VIII, *B, C, D,* may have been parts of the framework of an ancient house. The carving is even, uniform on both planks, and seems to have been done with sharp implements, but no marks suggest saws or other metal tools.

Plate VIII, *A,* illustrates one of two carved posts found among thirty or more stumps of posts on an old house site. The position of the two carved posts suggests that they had belonged to an older house. This view is supported by the fact that on each post the carved design (fig. 2) is interrupted

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at the top of the post, indicating that it had been disregarded by the builder in cutting his timber. Furthermore the house last standing on the site is remembered by living residents, who said it had been erected about fifty years ago, to replace a former structure. They also said that the house they remembered was of the more modern type. There still stand in three places poles said to have been posts of ancient houses, but none of them is carved.

The three-legged stool (Pl. VI, *D*), carved from one block of wood, was said to be a poi-board, but is unlike any in use at the present time; the mod-

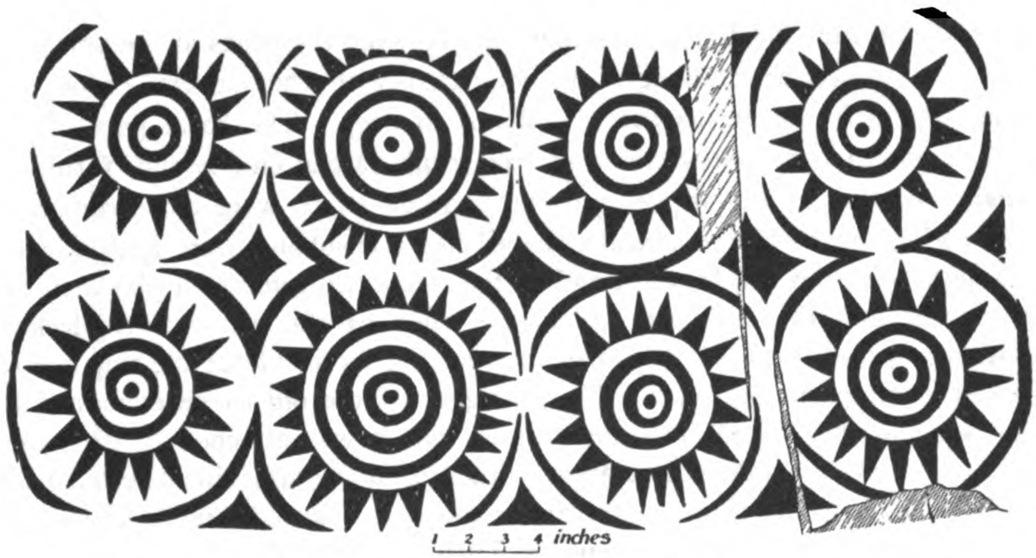

FIGURE 2.—Reproduction of a design on a house post.

ern ones are large and have four legs. The stool has not been in use for many years; the oldest member of the family from which it was obtained remembered it as part of the household furniture when she was a child, some sixty years ago. I was told by another in defiance of the informant that it was dug up while preparing a taro patch on land that for several generations had been unused. This story may well be true. Not over ten per cent of the land formerly utilized is now under cultivation, and it is altogether probable that turning over the soil of forgotten homesteads will bring to light other relics of the old culture. And it may be that both stories are true, and that the exhuming of this buried heirloom may have taken place before the old lady's memory began to function.

CANOES AND CANOE MAKING

At the present time there is no cult of canoe builders in Tubuai, although certain men are recognized as being particularly skilled in the work. And no ceremonies are attendant upon the building of the canoe, except that the

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builder may be the guest of the owner during the period of labor on the canoe. I was told that in former times the building of canoes was the work of men who did nothing else, but how they were chosen, how trained, and just how the work was conducted I could not ascertain.

Nothing is known of the primitive Tubuai canoe. The canoe spoken of as the older type is that commonly used in Raivavae. This canoe was made without nails, its various parts being tied together with sennit. Strips of tortoise shell, placed underneath the lashings next the wood, helped to make the joints water-tight and prevented chafing of the lashing. Strips of old sail cloth or wide flat braids of sennit, laid between the edges at the points of juncture, served as caulking. As compared with the modern canoe, the older type was longer, narrower and not so deep. The basal part of the hull, hollowed from two sections of tree trunk, lashed end to end, formed a smaller portion of the whole, and the gunwale strips were more elaborate. The end strips, both fore and aft, shaped like a wishbone, were integral with the deck, which at the forward end of the canoe projected as a platform for 3 feet beyond the cutwater. Only the ends of the canoe were decked. Bosses or projections left at proper intervals on the inside of the side boards served as supports for seats. The outrigger of the old canoe examined by me was missing. Some informants said that it was attached to the canoe by small sticks as is done at present; others said the attachment was a hoop of wood like that in modern Raivavaen canoes. The old Tubuai canoe had no step for a mast. At present in Tubuai nearly all canoes more than 16 feet in length have provision for masts, and many are sailed.

The canoe now used in Tubuai resembles closely those in use in Tahiti. The hull consists of from one to ten or more parts, but the basal portion consists of one piece. If possible, this basal portion is made of such size that it forms not only the bottom, but also the sides up to or above the water line. This prevents leaking. To this basal portion are added the pieces which complete the sides, the gunwales, and the forward and after decks. The number of such pieces is not fixed: some canoes are made from a single log, so fashioned that only gunwale strips and decking are needed to complete the hull. The outrigger float is a straight pole, the forward end dressed on the under side to give the effect of a slight up-curve. To accentuate this form, advantage may be taken of a natural curve in the wood, but in general the upper side of the float is straight. The float is longer than the hull, and is so attached as to project beyond the forward end of the hull. In the sailing canoe this projection is greater.

The forward boom is trebly curved, and attached directly to the hull by lashing, indirectly to the float by sticks and lashing. The boom projects from 2 to 3½ feet on the portside, this projecting portion serving as a han-

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dle in beaching the canoe or lifting it over obstructions. The projecting portion curves upward from the hull, corresponding to the arch of the boom on the float side. On the float side, always the starboard side, the boom

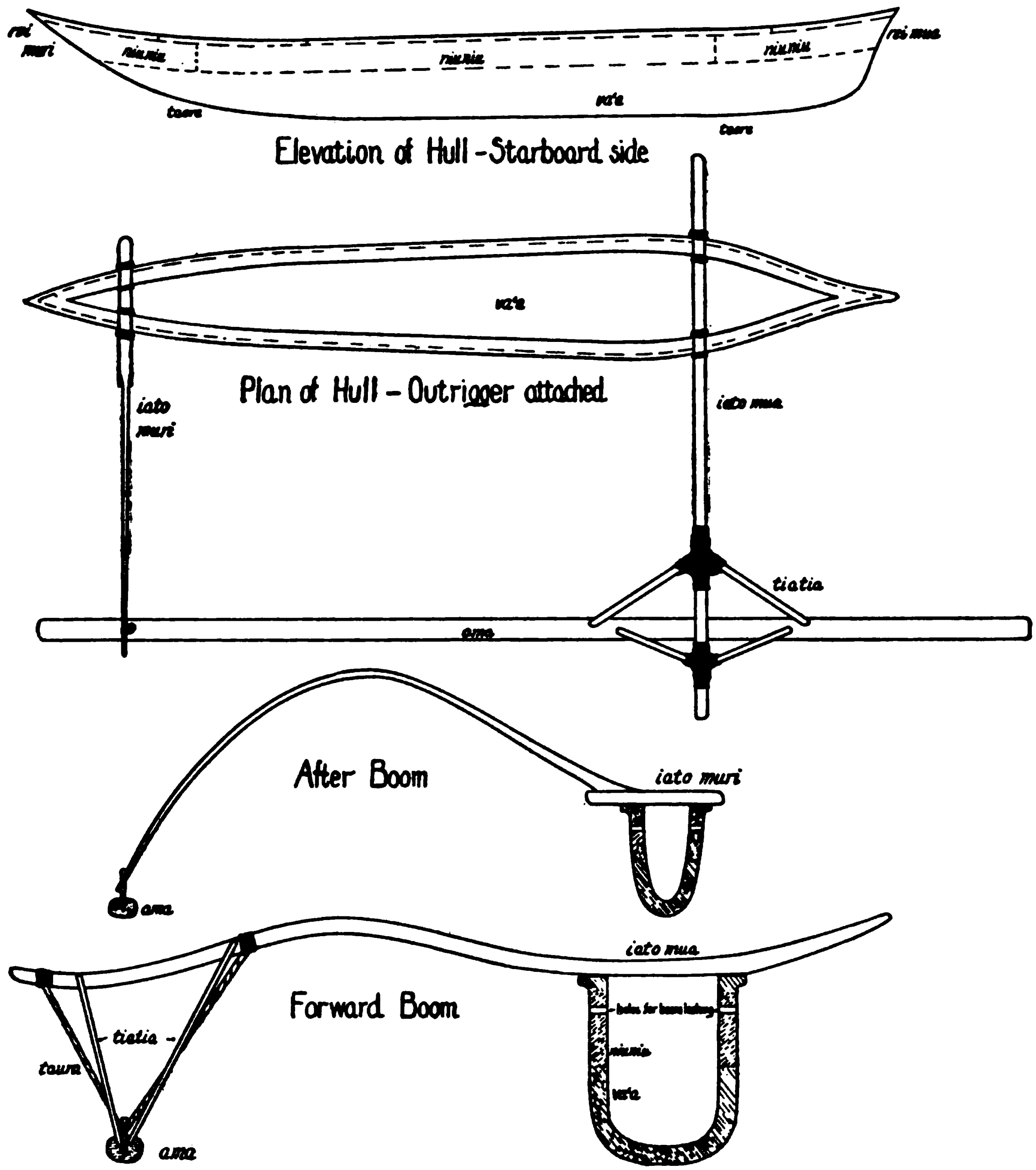

FIGURE 3.—Detailed drawings of a modern Tubuai canoe. (Scale of boom plans is twice that of hull and outrigger plans.)

arches upward from the hull, curving down to the point directly above the float, there curving sharply upward again. It projects just far enough beyond the float for the attachment of the tension member of the float. (See fig. 3.)

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The after boom, unlike the foreward boom, is flexible, and is curved in a high arch from the hull to the float. A favorite method is to cut a portion of the trunk of a small tree, just where a branch emerges. The section of trunk is lashed across the gunwales and the branch arches over to the float, where its end may be inserted in a hole, bored for that purpose, but commonly the attachment is indirect.

An additional boom, projecting 2 feet or so on either side of the hull, may be lashed amidships if the hull is very long; it is not attached to the float, and serves merely as a rest for fish spears.

Two sailing canoes observed have an additional spar, shorter and of less diameter than the float, lashed to, and lying parallel with the float. I was told that this spar was added because the original float was too small and would be discarded when the right size was obtained.

The seat in the ordinary one-man canoe, is a rough piece of board laid across the gunwales without attachment. In some canoes the seats are let in to the gunwale strips an inch or so, and in the larger canoes, especially the well-made sailing canoes, three or four seats are let in to the strip immediately below the gunwale strip, and so held in place. No canoe was seen in which a lug or projection was provided as support for the seats. In the old-time canoes this arrangement was the rule.

The space, forward and aft, respectively, of the fore and aft booms, is decked over with strips of plank, nailed in place with ordinary wire nails. This decking may end flush with the sides, or may project an inch beyond. These platforms provide standing space for the man wielding the fish spear. To drain the canoe when beached, a hole is bored in the bottom of the hull, aft, and fitted with a wooden plug.

The furnishings include one or more paddles, a bailer, and an anchor with mooring line. Sailing canoes have in addition the necessary equipment of mast, boom, and sail, with rigging. For a bailer a half coconut shell or any convenient receptacle is used. No trace was found of a specially designed bailer.

The anchor is generally a stone of convenient form and size, weighing about 20 pounds, secured by a line of braided sennit. The weight of the average anchor stone is about 10 kilos. Iron ballast, being less clumsy, replaces the stone when it can be had.

When drawn up on the beach, the canoe is carefully covered with coco palm leaves, sometimes woven together into a sort of mat, held in place by stones, usually attached to the ends of 4 or 5 foot sticks. If possible, a densely shaded place is selected.

Most of the paddling is done on the starboard side, the side toward the float. Almost no poling is done in Tubuai, although there are many places

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where the water is shallow enough to make it possible. At low tide or when paddling over the reef the butt of the fish spear or the paddle itself is used as a pole to propel the canoe or to ward off rocks.

Of 30 canoes measured, the largest is 21 3/4 feet long, 37 inches deep, 25 inches wide. The corresponding measurements for the smallest are 9 1/4 feet, 18 inches, and 17 inches. The average of all the measurements is: length of hull, 14 3/4 feet; depth outside, 21 inches; depth inside, 19 inches; width outside, 20 inches; width inside, 14 inches; length of float, 17 1/2 feet; center line of hull to center line of float, 5 1/2 feet.

Mast, boom, and paddles of canoes are generally made of hau (*purau*). The bailer may be a half coconut shell. The lashing material is always sennit, except when cord made of hau bark has been made for temporary or emergency use. Hau bark ropes are used for rigging. Sails, now made of canvas, were formerly either mats of lauhala or tapa of the coarsest grade. The woods used for making the hull, arranged in the order of their preference for this purpose, are: hau (*purau* or *fau*), *vi, ati* (*tamanu*), *tui tui* (*tiairi*), *tira, hutu, uru* (*maiore*). For the after boom and connecting sticks *aito* (toa) and *tuvava* are also used.

The following canoe terms are in common use:

Taere. Keel or bottom.
Vaa (va'a). Basal part of hull.
Niuniu. Side pieces.
Rei mua. Prow.
Rei mura. Stern.
Tua ura. Fore platform or deck.
Iato mua. Fore boom.
Iato muri. After boom.
Ama. Float.

Sticks indirectly attaching fore boom to float.

Tia tia. Spear rest.
Manu. Plug.
Orei. Mast.
Tira. Spar.
Too (to'o). Sail.
Ie. Paddle.
Hoe. Bailer.
Tatariu.

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WEAVING

METHODS AND MATERIALS

The mat and hat weaving industry is not as well developed in Tubuai as in the neighboring island of Rurutu. The best mat makers in Tubuai are women who originally came from Rurutu, and Tubuai girls frequently go to these women for instruction. Written and verbal evidence shows that hat-making is a recent development. The early visitors to the islands of this group mention turbanlike headgear, but not hats, and the shapes of the present-day hats do not differ from those found in any other civilized community.

However, mats and baskets have been made since the earliest times, for even the first records and the oldest traditions mention them. Hina, the cannibal woman of Rurutu, who is one of the favorites in nursery tradition, devoted her time weaving mats (p. 109), and Unutea, the princess of Tahiti, who came to Tubuai to become the wife of one of the chiefs of early days, found her brother's body wrapped in mats (37). Temātauira, the hero of early times in Tubuai, carried bundles and baskets of food on a voyage.

The making of mats and baskets, and of hats, is essentially the work of women. I saw no man making any of these articles, with the exception of the coarse baskets of coconut leaf, which are made by both men and women. Young girls are taught by older girls, or by their mothers, but spend little time at the work. In Rurutu, many girls not over six years of age work regular, long hours at weaving and are quite as skilled as mature women of Tubuai.

Before the actual weaving comes the culture of the *Pandanus*. It is planted conveniently near the home, and cared for as any other crop might be. The variety used for weaving is not the ordinary wild *Pandanus,* but a so-called tame variety (*Pandanus inermis*), the leaves of which are without thorns. These leaves are gathered and hung to dry on the ridgepole of a large house or in other sheltered places, where there is free circulation of air. For drying, the leaves are so plaited that they hang from the braid as a long fringe, only the tips of the leaves being included in the braid. The desired light color is obtained by drying in a place where sun and moisture cannot affect them. Occasionally leaves of the wild *Pandanus* are boiled; they are then almost white in color. But boiling robs the leaves of strength, and the articles woven are not durable.

The dry leaves are sorted and those that are too dark or too badly spotted are discarded. The remaining leaves are smoothed by drawing them between thumb and finger, and rolled in flat, circular bundles 12 to 18 inches in diameter. When needed for use the leaves are removed from the

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roll and further smoothed by drawing them over the back of a knife, or a similar dull, straight edge. A thrifty housewife contrives always to have a supply of these rolls of material on hand, so that a hat, mat, or basket may be made without the need of waiting for the green leaves to dry. Yet an experienced mat maker prefers fresh material, as she considers old stock likely to be discolored or brittle.

When ready to start weaving, the material in the rolls is again sorted. If the article is to be a particularly nice one, only the longer, more evenly colored leaves are used. These are smoothed with the aid of the knife blade, care being taken not to scrape the surface or break the fiber. This smoothing process has the additional effect of limbering up the material so that it will not break in the weaving. The leaves are next split into strands of the width needed for the work in hand, and done up in hanks or bundles of convenient size. The leaf is split with a pin or needle, or with the thumb nail. A woman with whom mat weaving is a regular occupation regards the nail of her right thumb as an indispensable tool, and keeps it trimmed to a rounded point projecting about a quarter inch. The longitudinal ribs, showing on the under side of the leaf, serve as guides for splitting. So reliable are these guides and so expert are the weavers, that a square foot of an ordinary mat, selected quite at random, contained only two strands that varied as much as 5 per cent from the average of all. The strands are wide or narrow according to the work at hand. One of the finest examples I have seen of Tubuai weaving is a hat made for me in imitation of a panama; it has 30 strands to the inch. The ordinary mat, however, has only 6 or 7 strands to the inch, and a coarse mat may have strands 1/2 or 5/8 inch in width.

MATS

In weaving a mat the operator seats herself on the floor or on the ground so that she may hold down with one foot the part just woven, and shift her position from time to time as the work progresses. In detail the process of weaving is as follows:

The mat is commenced by combining 3 to 7 strands in a right-angle triangle, the apex of which, placed at the left hand of the operator, is the initial corner of the mat. One side of this triangle extends directly away from the weaver, the other toward her right hand. More strands are added to the near side of the triangle, forming a substantial braid from which the free ends of the strands extend forward, diagonally in both directions. The near edge of this braid is the initial edge of the mat. When the braid has attained the desired length, it is finished by turning back and weaving in the final strands, forming in this way the second corner. All the strands necessary for the initial portion of the mat are now woven into the braid. The next operation is the interweaving of these strands, which is carried on a little at a time, working from left to right. The strip of completed mat added by each such operation is necessarily determined by the number of strands the operator finds convenient to handle. The weaving

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is continued until the ends of the shorter strands project only two or three inches beyond the working edge. If the mat is then considered sufficiently wide, the ends may be turned and woven back, forming a very firm, tightly drawn border similar to the initial braid. The length of good material is such that a mat one yard wide may be thus completed with this first set of strands. For wider mats, additional sets of strands must be added, the initial end of each strand woven in with the final end of the strand it serves to extend. I have seen a mat 75 feet wide, but the ordinary mat is about 7 by 9 feet; or if the house is large, 8 by 12 feet.

Making the final corner of the mat calls for the use of the only implement that is employed in the weaving. The last few strands must be threaded back into the nearly completed mat to form the corner, each strand following the course of one already in place. A bodkin is made from a thin strip of the midrib of a dry coconut leaflet about six inches long, with a blunt point at one end, and with the other end split. One of the tines at the split end is cut an inch shorter than the other. The end of the strand to be threaded back is inserted in the split end of this bodkin, and readily woven in its proper course. This same sort of implement is used when a broken strand must be replaced, or when an old mat needs patching.

After the weaving is completed, or even while it is in progress, the mat is rubbed with a smooth stone or with the bottom of a glass bottle that has a rounded base. Particular attention is given to the edges of the mat. The object is, of course, to smooth out irregularities and to make the mat lie flat.

The operator folds back the mat, in the course of weaving, so that only a few inches are at any time left free. This is to get the completed portion of the mat conveniently out of the way, to lessen the chance of unravelling, and to provide a guide by which the mat may be kept fairly rectangular. The folds are ordinarily 12 to 15 inches wide. The completed mat, in a sort of bolt, is doubled on itself, lengthwise, until the final bundle is of convenient size for storage or transportation.

HATS

The materials for hat making include *paiore* (hala: *Pandanus*), *ofe* (bamboo), *aeho* or *to* (a sort of grass), and pia. The hala is prepared as for mat making. The bamboo is prepared by removing the thin, highly glazed surface layer and splitting this delicate material into strips the required width. It is never used for men's hats. The outer layer of *aeho* stalk is prepared in a similar manner. The pia is seldom used.

The ordinary hat is made of hala (Pl. X, *B*).

The procedure is as follows:

The operator weaves several strands together at their mid points, forming a square or oblong figure the shape and size of which depends on the shape and size of the hat crown. From this initial figure the free ends of the strands project in four directions; additional strands are woven in with them, and the spaces at the corners filled in, until the figure assumes a circular or oval shape, with the free ends of the strands radiating in all directions. The operator adds new strands as needed, and continues this interweaving until the top of the hat block she selected is covered by the woven figure. She then binds the work firmly on the top of the hat block, and bends all the strands sharply down at its sides. The weaving then continues without additional material until the sides of the crown are completed. The operator then ties a cord firmly about the work on the hat block, at the lower limit of the sides of the hat crown, and bends the strands sharply outward. The block, which for the weaving of the crown sides was held on its side in her lap, is now set bottom up, and the weaving of the brim commenced. This proceeds exactly as did the weaving of the crown top, new strands being

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added from time to time, until the brim is considered sufficiently wide. The operator then turns the strands back, and finishes off the brim with a border or braid similar to that on an ordinary mat.

The hat block is a cylindroid of hard wood, varying in shape and size. Every hat maker has several blocks for the various members of her family, and new ones are readily made to meet special demands.

Bamboo, like lauhala, is woven directly into women's hats but is more commonly made into braid, which is later sewed into hats. Hat braid is also made of *aeho,* and if intended for very ordinary hats, even of lauhala. There is infinite variety of patterns in the hat braids, not only in the weave, but in the coloring of the different strands and in the combinations of braid in the hat.

BASKETS

There are several types of baskets. One type is made of lauhala by adapting mat-weaving technique. It is simply a continuous strip of weaving with the free ends of the strands finally brought together and braided or sewn firmly into a seam. The resultant basket is flat, rectangular in its longest cross section, and of whatever dimensions the weaver chooses.

The more common baskets, and those I believe to be more characteristic, are made of coconut leaves. The simpler roughly made baskets are used for carrying taro home from the patches, for holding food to be cooked in the umu, and for similar temporary service.

In making such a basket, the operator cuts a section of coconut leaf as long as he wishes the greatest dimension of his basket to be. He weaves together the leaflets on one side of the rachis, then those on the other side, the weave being a simple checkerwork. The end leaflets on one side are interwoven with the corresponding leaflets on the other side, and finally the bottom is formed by braiding the free ends of all the leaflets together. Such a basket may be woven directly about its burden; the rachis serving as a handle which is split to empty the basket. Ordinarily, however, the rachis is split when the basket is completed, the ends bent around and bound on the opposite sides, the split rachis thus forming a very substantial rim, to which are attached cords for carrying handles.

The more elaborate coconut leaf baskets are made in a somewhat different way.

The rachis is split, and most of the woody part cut away, leaving only enough to support the leaflets, which are folded along their individual midribs. The two halves of the leaf are laid with the rachis parts together and the leaflets inclined oppositely. The folded leaflets are first twined about the rachis, then interwoven in a twill, the ends of the woven strip being brought together so that the end leaflets may be interwoven, the whole forming an endless strip with the rachis parts for one border and the free ends of the leaflets for the other. These free ends may be united in a single or double braid, making the shape of the basket flat vertically like an ordinary brief case (Pl. IX, *A*, *B*), or they may be interwoven in a continuation of the twill for the sides, forming a basket with a square bottom. (See Pl. IX, *C*; X, *A*.) This bottom

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is of course double, each leaflet extending across it along the course of the corresponding leaflet from the opposite side. The rims of such baskets, whether flat or square, are generally reinforced by wrappings of hau bark or sennit. Cords of like material are attached for carrying handles.

FANS

Fans are little used in Tubuai. The style of weaving is shown in Plate X, *C*. All fans are made of lauhala, with bamboo or other light wood for the handles. For the decoration dark colored strips from the surface layer of the *fei* stalk are used.

DECORATION

Mats, hats, baskets, and fans are ornamented by variations in weave, by the interweaving of colored material in addition to the regular strands, and by the coloring of the individual strands before weaving. Various combinations of these methods are also made, as for instance, in the *pupure* (spotted) hats colored material overlies strands which themselves form patterns in the otherwise plain weave.

Variations in the weave without the introduction of color are met with in all the forms of weaving, but are most frequent in hats and baskets. For example, a hat crown may have a band about it in which the strands simply lie without interweaving, or in which each strand, instead of passing alternately under and over the strands running in the other direction, passes alternately under pairs of those strands. The variations in weave are endless. Many of them are known by specific names in Rurutu, but not in Tubuai.

Many mats and hats have colored borders, made either by interweaving colored strands, each overlying one of the strands of the regular material, or by embroidering with the colored strands. Interweaving is the more common.

In hat braid there is great opportunity for decorative effects. Bamboo takes dye well, and even delicate colors stand out sharply in contrast to the snowy white of fiber. Colored strands are mingled with white strands in definite combinations, and by varying these combinations and the weave itself, an almost infinite variety of decoration is possible. Strands of *aeho* also are dyed, and much of the hat braid made with them is dainty. I have seen braid with 46 strands to the inch in which a half dozen colored strands formed a very pleasing pattern.

These decorative designs appear to be almost entirely modern. It may be that a close and extended study would reveal some ancient patterns, but I am inclined to think that modern dyes, modern materials, and the stimulus of foreign examples have largely controlled the development of this decorative art in Tubuai.

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TRAPS AND SNARES

There is no evidence that artificial fish traps, pounds, or ponds ever existed in Tubuai. There are, however, two fish pounds formed by nature. One of these is the lagoon itself. A long section of the barrier reef, awash only at high tide, is broken by an opening only a few feet in width. Fishermen sometimes stand at the sides of this pass at ebb tide, and spear the fish passing through from the lagoon to the open sea. The other pound is a natural depression in the bed of the lagoon near Tamatoa. The water on all sides is quite shallow, but the depression is 40 or more feet in depth. Many fish find refuge here, and it is consequently a favorite fishing ground. It has never been stocked artificially.

No basketry traps for fish or crustaceans are made in Tubuai. The *Freycinetia,* the roots of which elsewhere in Polynesia provide the best material for such basketry, does not grow on the island. The few old men who understand the weaving of such traps said that they had learned the art elsewhere.

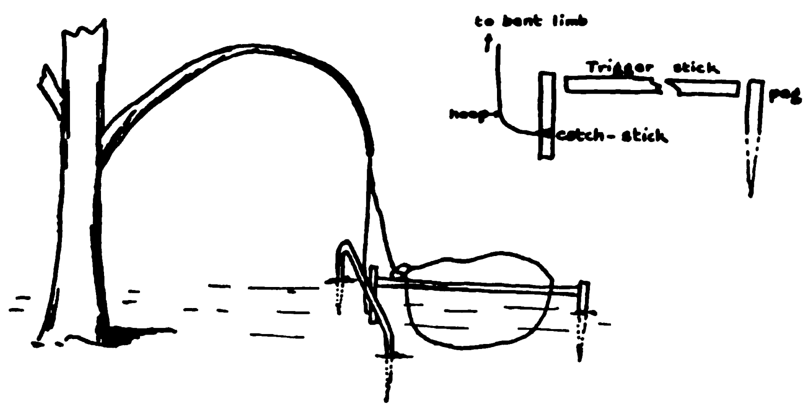

FIGURE 4.—Diagram of a trap for catching birds.

Snaring of birds is practiced in Tubuai. (See fig. 4.) The method used is said to be very old, but is quite similar to one I learned as a boy in California. The process may be described as follows:

A place is selected where the birds are known to feed, and where a convenient tree or bush will provide the necessary spring to draw the snare. Both ends of a tough stick are thrust vertically into the ground, a short distance from the tree or bush selected, forming a hoop the top of which is about 3 inches above the ground. Opposite the center of the hoop, and about 1 foot from it on the side away from the tree or bush, is driven a short peg. A limb of the tree or bush is stripped of leaves and bent down until its tip is near the hoop. To the tip is attached a cord, the other end of which is brought under the hoop and tied to one end of a short stick. This catch stick, about 3 inches in length, must rest against the hoop, standing vertically, and project 1 or 2 inches above the hoop. From its upper end to the peg is laid another stick, its length such that it just holds the catch stick in position against the hoop.

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Finally, a noose is tied in a second cord, the free end of which is passed over the hoop and tied to the bent limb. The noose is spread over the horizontal or trigger-stick and grated coconut sprinkled within it as bait. When the intended victim steps on or brushes against the trigger stick, it is readily displaced, the catch stick is released, and the bent limb springs back to its upright position, taking with it the noose and sometimes the bird. I have seen wild duck and chickens caught in such snares and it is said that other birds are also taken.

Snares tied in the ends of long cords, with the free ends held by children concealed in the bushes are sometimes used to catch wild ducks, but generally the victim is a domestic fowl run wild, or one of the home flock too wild to be caught readily. Similarly wild or domestic fowls are sometimes caught beneath a box or crib-work of sticks, one end of which is propped up by a single stick. The operator, generally a child, sprinkles grated coconut as bait beneath the box. He then conceals himself in adjacent shrubbery and by means of a long string attached to the supporting stick, displaces it, catching the fowl when it is fairly beneath the trap. No other traps or snares are in use or known, except, of course, a few modern rat traps.

ROPES AND CORDAGE

Cordage in Tubuai is made chiefly from sennit and from hau bark. Fibers of the banyan and of certain ferns are twisted into cordage, especially into that used for fishline. Much of the rope in use on the island is made with iron cranks, or wooden imitations, which form part of the equivalent of a ropewalk. (See Pl. XI.) Similar three-strand twisted rope is made by hand, but only when the irons or their substitutes are not available. The best cordage is the sennit, still made in the primitive manner. The process as I observed it is as follows. (See Pl. XII, *C*.)

Mature coconuts, the largest to be found, were stripped of their husks. The husks, soaked thoroughly in water, were cooked for two days in an umu. When they were removed from the umu, they were soaked again for several hours. The operator took a husk from the water, laid it across a log, and pounded it vigorously with a heavy stick. This, he explained, was to loosen the fibers. He next stripped away the hard outer layers of the husk, and the more spongy inner layers, and again beat the fibers, this time lightly. From time to time he shook out the non-fibrous matter, and finally, when the fibers seemed quite clean, he tied them by one end in a bunch, and spread them in the sun to dry. A half hour sufficed for the drying. After discarding his trousers in favor of the more convenient *pareu*, the operator pulled half a dozen fibers from the bunch and rolled them between the palm of his right hand and the upper surface of his naked right thigh (Pl. XII, *A*) adding more fibers from time to time, until he had a strand a yard or more in length. He made three such strands, knotted them together at one end, and, tying this end to the great toe on his left foot, braided them together into the finished sennit. (See Pl. XII, *B*.) He explained that in ordinary practise more material would be twisted into the strands, extending them indefinitely, but that they were always braided as fast as they were extended lest the separate strands become tangled.

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The operator demonstrated a second method of combining the strands:

Holding two strands parallel and touching, he laid them across his thigh, and placed the palm of his hand upon them. Moving his hand slowly, he rolled the two strands separately but simultaneously until they were tightly twisted, then with a quick sweep of his hand he combined them in a single twist. There is quite a knack in attaining just the right degree of twist, and in combining the two strands without losing too much of it. The operator said that he did not like this method, as it made his leg sore, but said that when he was a boy he watched old men, sitting together talking, roll sennit for hours at a time. The other fibers used for rope or cord are twisted in the same manner as are the coconut fibers.

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TAPA AND FEATHERWORK

In various early records there are repeated references to tapa from the Austral Islands. Rurutu was especially noted for the quality of its product, and Tubuai is also mentioned. Brigham lists no tapa from the Austral Islands. It may readily be, however, that some specimens credited by him to Tahiti were actually made in Tubuai. Seale (39) reported that at the time of his visit, in 1902, tapa making was already a lost art, and specimens were no longer readily obtainable. He, however, obtained one sample of tapa. It is undecorated white, made of breadfruit bark, and measures 5 1/2 by 11 1/2 feet. The two specimens obtained by me are presumably also of breadfruit bark, but are dyed red-brown, probably with infusions of *toa* bark. One of them measures 8 feet by 5 1/2 feet, the other 8 feet by 6 feet. Both bear traces of a glaze, or varnish, which was applied to one surface only. The woman, about seventy years old, from whom I obtained them said they had been made for her mother by her mother's mother, and that they had been used at the time of her own birth and at the birth of each of her numerous brothers and sisters. If her account is correct, these tapa were made in about the year 1850. They had been stored away for many years when the old woman reluctantly produced them; only she knew of their existence.

Mr. Eugene Doom, of Tubuai courteously gave me a tapa which he obtained in Rimatara in 1910, or perhaps a few years earlier. At that time, he said, the industry still flourished in that island, and this tapa was quite new. It was then a single piece about 6 feet by 20 feet. This tapa has its natural white color, is undecorated, and probably is made of breadfruit bark.

Further evidence of the extent of the ancient industry in Tubuai is the large number of tapa beaters or mallets. (See p. 64.) The Tubuai people are reluctant to part with these implements, saying that if ever they wish to make tapa the mallets will be needed. I am afraid, however, that no more tapa will ever be made there, and that the remaining mallets will be lost, destroyed, or worn out in household use as many others have been since the death of the tapa-making industry.

I examined two anvils (*tui*) upon which tapa was beaten. Both had seen much service, but were well preserved, except that some forgotten house builder had used them as sills for the side walls of a dwelling, and had shortened them to fit his plans. They are about 18 feet long, 5 by 8 inches in cross section. They are made of thoroughly seasoned hard wood, one of *ati*, the other of *tou*. I was told that some ancient *tui* were as short as 10 feet, and that the longest ones measured as much as 75 feet.

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Mootua, the old woman from whom two old tapas were obtained, remembered having helped, as a girl, in the making of other tapa. I persuaded her to make a small sample for me, using old-time materials and methods as nearly as she could remember them. (See Pl. XIII.) She demanded *aute* as her material, which delayed operations considerably as only a few small plants were obtainable.

The inner bark was separated from the outer, and from the solid portion of the branch. The resultant strips of material, each about 1¼ inches wide, and 30 inches long, were first beaten lightly, then set aside for a day, and again beaten lightly. Previous to the first beating, and again in the interval between the first and the second beating, the strips were rolled in bundles and soaked for about ten hours in running water. The implements used in beating were the *tui*, made of *tou* and a set of *ie tutu* (tapa beating mallets), made of unidentified hard wood. The anvil was placed within doors part of the time, and under a half-open shed the remaining time. I persuaded the operator to place the *tui* out in the open for the sake of a photograph, but after the picture was taken the anvil was carefully replaced in the shade. The *tui* was raised slightly at each end on small blocks of wood; when struck, it gave out the resonant note commented upon by all writers on tapa making. The operator sat on the ground, her knees flexed, her feet pointing outward at each side. Occasionally she varied this posture by crossing her legs "Turk-fashion." She had selected a particularly smooth place on the anvil for her work, and sat herself opposite and within easy striking distance. The bark strips were laid across the anvil. When the portion of material on the anvil was sufficiently beaten, it was moved forward on to a banana leaf laid on the ground to receive it, and a fresh portion exposed on the anvil. The operator grasped the mallet in both hands, and struck smart, but not heavy, blows, bringing the mallet down quite squarely each time. She said that if she were really accustomed to the labor and performing it quite properly, she would use two mallets, one in each hand, and would, if possible, have one or more friends beside her, similarly equipped.

After the preliminary beatings the strips of material measured about 6 inches in width and slightly longer than the original stalk. Four of the six strips were then arranged carefully, the first spread its full length and width along the timber, the others superposed, in turn, care being taken to spread the net-like fabric of the strips so that there were no thin spots in the completed pile. The edges were next folded back almost to the mid line, making a strip about 3½ inches wide, 8-ply, with even, smooth edges. The ragged ends were cut off square, and these pieces, together with the other remaining strips, were laid aside for use in building up thin spots which might appear during subsequent beatings.

The next operation consisted of the beating of the 8-ply mass to its final dimensions. The position of the hands relative to the work changed frequently so that the graining of the finished material was fairly crosshatched in all directions.

From time to time the material was moistened by raising it from the anvil and passing the hand, dipped in water, along the surface of the timber. At one time this moistening was neglected too long and the material stuck to the timber; but patient, gentle effort freed it. The operator explained that care must be taken to prevent the material from becoming either too moist or too dry; if too dry, it sticks to the anvil or to the mallet; if too moist, it spreads too readily under the blows of the mallet, and the finished product is uneven.

These beating operations were continued until the operator judged that further beating would make the tapa too thin and weak; indeed, there were already a few perilously thin spots near the edges. The material was then carefully spread out in the sun, on an old mat, and left until quite dry. It was then so stiff that it could be lifted by an edge or corner. This stiff, wrinkled oblong sheet was set aside until there was promise

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of another clear day (several rainy days intervened). It was then left out of doors overnight, to become softened by the dew. In the morning the operator worked the tapa about in her hands, crushing, crumpling, and smoothing it, always gently, until all stiffness was gone. It was then again dried in the sun: this time stretched out to its fullest extent with stones set on edges and corners. When dry it was relatively soft and pliable. The operator said that to make it quite soft several such exposures to the dew and subsequent treatments would be required.

The operator explained that had she been able to complete the work in a single day, or even two or three days, the product would have remained perfectly white, its natural color. Through delay, however, it had become somewhat discolored. In response to my request to have a part of the sample dyed, she prepared a red-brown dye, saying it was the one commonly used in former times.

The dye was an infusion in cold water of finely grated *toa* bark. When the infusion was considered sufficiently strong the bark was strained out with a swab of *aa*—the fibrous material from the base of a coconut leaf petiole. The tapa was dipped in the dye, allowed to become saturated, then carefully wrung out and dried in a shady place. Before quite dry the sun had worked around to it; consequently the surface then uppermost was slightly bleached.

The operator explained that the tapa might readily be cleaned in cold water by rinsing and very gentle rubbing and squeezing. If a hole needs mending, she said, it can be patched with new material by fraying out the edges of the torn place, and placing over the space a small piece of new material, prepared except for drying, then beating until the old and new are smoothly united. Before beating, the frayed edges of the old material must be carefully worked into this soft, new stuff. If this is done skillfully, a patched place can hardly be noticed.

A second woman offered to make a piece of tapa. I encouraged her to do so, and watched its preparation. Her procedure differed only in minor details from that of Mootua Vahine.

Besides the two pieces of tapa, I obtaind also the *ie tutu* (tapa mallets) used by Mootua Vahine. In the first operation, two faces of the mallet shown in Plate VII, *C*, 1 were used, each of which had three deep V-shaped grooves. The other two faces with eight shallow grooves in each were not employed. This mallet was used only for the pounding of the separate strips of material. When these strips were laid together and folded, they were beaten with another mallet which had seven grooves (Pl. VII, *C*, 2), only one face of the mallet being used. The mallet was badly worn, particularly on the other faces. When the work of beating out the folded material was about one-third completed, the operator laid aside the second mallet and completed the work with a third (Pl. VII, *C*, 2). . . . Three

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sides of this mallet were used; the first had 18 shallow grooves, the second 29 grooves a little shallower, the third 60 grooves, amounting to little more than deeply scored lines. The fourth face, with 50 grooves, was not used, because of its partial defacement. The final work on the tapa was done with the beater having 60 grooves. Mootua Vahine, the operator, declared it to be a very excellent implement.

All of these tapa mallets appeared very old; the hard woods of which they are made have not as yet been identified. They are said to have been made only of *toa*. The anvil on which the tapa was beaten was made of any hard wood. Two were seen, one of *ati*, the other of *tou*.

Tapa making as an industry no longer exists in Tubuai. From two old women who as girls had made tapa I learned that among the plants used for fiber are *aute* (*aurii*), *uru* (*maiore*), *aoa* (*oraa*), and *purau* (*fau*). For yellow dye, *rea* was used; for brown dye, *aito* (toa); yellow and red dyes were produced from *nono*, black and brown from *tuitui* (*tiairi*) and a brilliant crimson dye was made by combining leaves of *kou* with fruits of *mate* (*mati*). For perfume *tiare tahiti*, *iahi*, *rea moeruru* (*pipi atai*), and *ati* (tamanu) were used. (See list of plants, p. 14.)

Featherwork is a lost art, if indeed it ever existed in Tubuai. Certain old legends casually mention feather decoration of canoes and of weapons. At the present time feathers are used only as lures in night fishing, and occasionally as hat ornaments by the women.

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MEDICINE AND SURGERY

MEDICAL PRACTISE

Tubuai is relatively healthful. There seems to be less tuberculosis than in the neighboring islands; elephantiasis occurs in only one form, and the only leper is an immigrant from Ravaivai. The scourge of venereal disaese is heavy, yet its evil effects are not as much in evidence as in many places; very few infants are in any way deformed or physically abnormal, and of three cases of blindness noted, at least one was certainly due to accident rather than disease. Deaths are due to ordinary natural causes, according to the official records, except when an unusual cause is imported. Records show that the island has several times been swept by epidemics, each of which reduced the population greatly.

Shortly after my arrival in 1921 an epidemic similar to typhoid fever passed through the entire Austral Islands, affecting for the most part the children and younger adults. I was one of the victims. There were several deaths, and many lingering illnesses with curious complications.

Of these complications the most frequent was some form of meningitis, generally fatal. There were no remedies: the native medicines did no good, and the call to Tahiti for medical assistance was ignored until long after the epidemic had run its course. The cost in lives was not so great in Tubuai as in Raivavae and Rurutu.

The French Government provides the resident gendarme with a small stock of simple medical and surgical supplies, but unfortunately for the people of Tubuai, the gendarme seldom understands their use. The medical officer from Tahiti who makes an occasional trip among the islands may or may not stop at Tubuai, at best his visits are infrequent. The Chinese merchants carry in stock a few simple remedies such as Epsom salts, castor-oil, and "Pain-killer," and local residents sometimes send to Tahiti for various patent remedies. But the amount of medicines and drugs received from the outside world is very small. Practically all the medical practise is by the people themselves, with remedies they prepare from local materials.

Two or three times I was in need of medical aid, and on those occasions was able to judge somewhat of the nature and effect of some of the native remedies. Certain of them were very effective, and others at least not harmful. Some really marvelous cures have been accomplished by the native "doctors," but on the other hand, many lives have been sacrificed because of the lack of scientific treatment.

No group of people in Tubuai devote their lives exclusively to medical practise: certain persons, however, are recognized as being wiser than others on the subject, and their aid is sought in treating unusual or severe sickness.

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From several such persons I obtained directions for preparing and administering medicines.

There appear to be two classes of remedies. The most important class includes a large number of medicines, the preparation of which is fairly well standardized according to formula or recipe. The second class includes remedies suggested by accident or incident, perhaps by a dream of the "doctor" or of the patient, perhaps by some curious coincidence in connection with the disease or with an act of "doctor" or patient. This class includes remedies and courses of treatment of great variety; in general they seem ineffective except where mental suggestion is the only cure needed. An old woman heard that I was afflicted with a boil; the next morning she started out to bring me her favorite medicine for boils. Along the way she noticed a broken branch hanging from a roadside shrub; a few feet farther on she noticed some green shoots of a certain plant: she plucked a few leaves from the shrub, and gathered a few of the green shoots. It happened that both are supposed to have medicinal value, so she brought them along to make into medicine for me, instead of the remedy she had at first intended to prepare. Medicines prepared in that manner, however, are not the rule. In general a definite, sometimes very complicated, standard recipe exists, together with a set way of administering or applying the remedy. For example, one remedy for a certain digestive disorder has five ingredients, besides water; half of the mixture is taken internally, the other half is heated, not over the fire, but by immersing in it a heated stone. The heated preparation is applied externally, accompanied by rubbing. Different people advise the use of different remedies to relieve a given condition; there are numerous medicines for a number of the more common complaints. But any one remedy varies only slightly, if at all. There may be a minor change in the composition, but such is generally to be explained by the carelessness with which various ingredients are measured.

REMEDIES

I present here a list of remedies whose preparation and methods of application have evidently become quite standardized. It is interesting to note that as in other phases of their life, the coconut plays an important, really an indispensable, part in the medical practise of the Tubuai people. Coconut water, the shell, coconut milk (the liquid expressed from the grated meat of the nut), edible coconut oil produced by "trying out" grated meat or milk mixed with pia or manioc starch, and *monoi* have their uses. A large number of the internal remedies depend on the water from coconuts for bulk; and many contain the edible coconut oil. Most of the external remedies contain the non-edible *monoi* (p. 18). The astringent effect of the

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juice expressed from the husks of green coconuts is utilized in several remedies.

In the following list of remedies the native plant names are used. The equivalent scientific terms are listed on pages 14-16.

LIST OF REMEDIES

Raau faahee. A purgative. With the meat of several dry coconuts, mix pia or manioc starch, cook slowly. Use the oil thus rendered as the purgative. Dose: one wine-glass full, or more.

Raau haamahuhī. Remedy for diarrhea. Squeeze the juice of young *rautî* leaves into coconut water. Dose: half a tumblerful, four times daily.

Raau hea. Remedy for a disorder of children, rarely of adults, one symptom of which is the passing of clouded urine. To the milk of four dry coconuts add the following plants, crushed: *paifee,* 3 plants; *avaturatura,* 1 handful, new plant; *tiare tahiti,* 5 immature blossoms; *mairi taurahui,* 1 handful, new plant; *amia,* 1 handful, new plant. Pia or manioc starch may also be added. Dose for children: two table-spoonfuls of the liquid; for adults: one ordinary glassful.

Raau hea. Second remedy. To the milk of 3 green coconuts add the juice of the following: *mapua no'ano'a,* 1 handful; *tiare tahiti,* 30 tips of twigs; *pipiatai,* 1 plant; *tiairi,* 2 nuts. Dose: small quantity of the liquid at frequent intervals.

Raau omaha rearea. Remedy for "yellow urine." To the juice of half a green coconut husk add the following crushed: *fautia,* 1 handful, young plant; *tamore,* 1 handful, young plant; *miri uaua,* 1 handful, young plant; *mapua no'ano'a,* 1 handful, young plant. To half of this mixture add ½ cup fresh water and strain. Dose: one-third the liquid at morning, noon, and night. Heat a stone and place it in the remaining half of the mixture; when liquid is comfortably warm, rub upon the abdomen. Repeat the external treatment as often as desired.

Raau ira. Remedy for some internal disorder, not diagnosed. To the meat of six dry coconuts add the following, crushed: *tainoa,* 1 handful, new plant; *ora,* 1 handful, new roots; *tutu,* 1 handful, new shoots; *amia,* 1 handful, plant; *patoa,* 1 handful, plant; *toroura,* 1 handful, plant; *upa,* 1 handful, plant *vainu,* 4 new tops. Thicken with pia or manioc starch, and cook slowly. Dose: adults, one tumblerful.

Raau pua. Remedy for inflammation of breast or abdomen. Crush the following ingredients: *nono,* 2 ripe fruit; *nono,* 2 green fruit; *nono,* 4 green leaves; wrap in cloth and apply to affected parts as a cold compress. When partly dry, renew.

Raau fefe. Remedy for boils. Crush one new top of the *mata pio* and two new tops of *haato;* moisten with *monoi,* scented or not, and tie in cloth. Rub the region about the boil first with *monoi,* then with the remedy.

Raau fefe. Second remedy. Crush 2 roots of *avaavairai* and 2 roots of *pipiatai;* mix with small amount of *monoi;* tie in cloth and rub lightly in circle about the boil.

Raau taupo. Remedy for severe boil, or carbuncle. Moisten with *monoi* 1 handful of crushed *matia tatahi,* and a like amount of crushed *patoa,* scented or unscented; tie in cloth, and rub in a circle about the center of the affected area. (In my notes I have written *matia tatahi;* it probably should be *matie tatahi,* which may be translated "beach grass," as the plant is a sort of grass found commonly near the beach.) This remedy is supposed to allay the pain and "bring to a head" the boil or carbuncle. I can testify as to its soothing effect from personal experience.

Raau fati. Remedy for broken bones, or severe contusions or bruises. Crush 10 six-inch pieces of *tiatia moua* and the same amount of *metua puaa.* Dose: 2 or 3 ounces of the juice. For external application, moisten the crushed plants with *monoi,* and tie in a cloth, dip in cold water, then squeeze onto the affected part. Rub very lightly with the finger tips. Repeat three times daily. One mixture will suffice for

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two days' treatment. This treatment may continue for several weeks, the patient remaining as motionless as possible.

Raau mahaha. Remedy for pain or congestion in the chest. Crush 7 pieces of the stalk of *tiatia moua*, a like amount of *metua puaa*, also 1 handful of the green buds of *tiare tahiti;* express juice into the water from 2 green coconuts. Dose: one-half glass of the strained pulp, five times daily. Do not keep more than two days.

Raau uaua. Remedy for stiff neck, cramp, neuralgia. Crush 1 handful of *niroahiti* and 1 of *patoa;* moisten with *monoi*. Prepare a sieve by drawing several stalks of *mauu* between two sticks to loosen the fibers. If *mauu* is not available, the inner bark of the hau or breadfruit tree may be used. Holding the fibers at both ends, place the mixture in the center and wring out the liquid. Rub the juice lightly on the affected parts about six times daily. Add more *monoi* after two days.

Raau tupito. Remedy for infant's inflamed navel. Remove rind from a joint of sugar cane, preferably the variety with a dark colored rind, and scrape the pulp. Squeeze out a small quantity of the juice and give to patient; tie the pulp in cloth and apply as poultice.

Raau pê. Remedy for any infected sore. To the scraped meat of 10 dry coconuts crush and add *ofe*, 1 handful new shoots; *aeho*, 1 handful new shoots; *pipi mamai* (*nanai*), 1 handful new shoots; *tianina*, 1 piece bark, 3 inches by 4 inches; *ati*, 1 piece bark, 3 inches by 4 inches; *purau*, 1 piece bark, 3 inches by 4 inches; *moe-moe*, 1 handful; *omohora*, 1 handful; *tiapito*, 1 handful; *haehaa*, 1 handful; *ava-avairai*, 1 handful; *teve*, 4 green plants; *tupu*, 4 green plants. Thicken with pia or manioc starch and cook slowly. Dose as purgative: 2 tablespoonfuls to one tumbler full, according to age of patient. Also apply the liquid to affected parts.

Raau pê. Second remedy. Crush 2 leaves of *ahia* and 2 of *autaraa;* add to the expressed juice the milk of 2 dry coconuts and pia or manioc starch; cook slowly. Apply the liquid directly to the affected parts. A small amount may be taken internally as a purgative.

Raau pê. Third remedy. Crush 1 handful of the new tops of *pipi atai*, add to the expressed juice the milk from ½ dry coconut, and apply directly. This remedy may be accompanied by a dose of the ordinary coconut oil purgative.

Raau haamahu toto. Remedy to stop bleeding. Express the juice from the crushed husks of 4 green coconuts and apply directly into the wound. If an open cut, not bleeding excessively, or after bleeding has been checked, apply a dressing of crushed fresh green leaves from the top of the *matapio* plant, bind lightly in place and leave for several hours.

Raau vaha pê. Remedy for inflamed or suppurating mouth or lips. Crush the following ingredients: *haehaa*, 1 handful entire plant; *tiapito*, 1 handful entire plant; *paihi*, 1 handful entire plant; *nohoahu*, 1 handful entire plant; *ofeofe*, 1 handful entire plant; *rimu pape*, 1 handful entire plant. Place in swab of inner bark from young breadfruit tree. Express juice directly into mouth of patient. Not to be taken internally.

Raau oromoo. Remedy for sore throat. *Taataahiara*, 1 handful; *tuitui*, 1 handful inner bark. Crush, and squeeze into about one quart of fresh water. Sweeten with white sugar, until like syrup. Gargle throat with this syrup, then at frequent intervals take a few spoonfuls internally. Do not repeat gargle unless condition is obstinate.

Raau taria mai. Remedy for ear ache or abscess in ear. Crush 6 red leaves and 6 green leaves of *tou* add a little *monoi ahi* [*monoi* scented with sandal-wood]. Express a little of the juice directly into the affected ear several times a day. If desired, the mixture may be slightly warmed before application.

Raau vari. Remedy for painful or suppressed menses. Mix with 1 handful of fine dust scraped or filed from the dry wood of *ahi* (*iahi*), the water of 4 green coconuts.

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Dose: half a glass of the liquid heated, followed by the same amount cold; repeat three times a day until cure is effected.

Raau huaira. Remedy for swollen testicles. To the juice of the following: 1 handful of *paihi*, 2 new shoots of *uru*, 2 new shoots of *paeore*, 2 new shoots of *nono*, 5 new shoots of *tiare maohi*, 1 handful of *niroahiti*, 5 nuts of *tuitui*, add the water of 4 green coconuts. Dose: one-half glassful, four to six times a day.

Raau opi. Remedy for gonorrhea. Crush and place in sieve made of *purau* bark: 1 handful of *niroahiti*, 1 of *paihi*, and 3 nuts of the *tiairi*. Express the juice into the water of 2 mature coconuts. Dose: a small amount of the liquid cold, followed by a like amount hot; repeat several times a day.

Raau opi. Second remedy. To the water of 6 green coconuts add the juice of the *mapua noanoa*, 1 handful; *moomoo*, 6 plants; *tiatia moua*, 6 plants; *tiare tahiti*, 20 blossoms; *moomoo*, 6 young shoots; *mouu puahu*, 12 plants; *pipiatai*, 1 plant. Dose: one glassful hot, one cold, four times a day.

Raau opi. Third remedy. Express the juice of a handful of *tamore* leaves, one of *niroahiti* leaves, and another of *moemoe* leaves into the water from one green coconut. The entire quantity is to be taken at a dose. Repeat once a day for three days.

Raau opi. Fourth remedy. To the juice of 2 green coconuts add the juice of the following: *mapua noanoa*, 1 handful; *tiare tahiti*, 30 immature flowers; *tiairi*, 2 ripe nuts; *pipi atai*, 1 root. The entire quantity is to be taken at a dose. Repeat four times daily.

Raau opi. Fifth remedy. Add the juice of 1 handful of the green cones of the *aito* to the water from 1 green coconut. Dose: entire amount, repeat once daily until cure is effected.

Raau mata pe. Remedy for sore eyes. Apply the juice from the bud of the banana to the affected eye. Repeat application several times each day. The juice may be collected most readily by snipping off the tip of the bud. I saw this remedy applied in Raivavae to the eyes of a five year old child, but did not learn whether or not a cure was effected. The child's eyes were quite inflamed, and the lids granulated as in conjunctivitis. I was later informed that the remedy is used in Tubuai and also in Rurutu, and that it is quite effective.

SURGERY

No major operations of any sort are now performed in Tubuai. I found no remembrance or tradition of any. All operations seen by me or described to me were minor ones.

The most frequently performed surgical operation is circumcision, or rather, superincision. All boys undergo this operation when from 12 to 16 years of age. It is said that in former times the operation was performed only by older men, usually by the father or grandfather of the patient. Now, however, the boys very frequently operate on one another. The operation is conducted with utter disregard of even the most elementary principles of surgical cleanliness. A bit of smoothed *toa* wood or other smooth, hard material is introduced between the prepuce and the glans penis at the top, and a longitudinal slit made with some sharp implement, splitting the prepuce from outer edge back to its beginning. A razor is now frequently used for the cutting; a new shark's tooth is considered better, and a newly split

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piece of bamboo is said by some to be best of all for the purpose, as it is free from rust and other contamination, and therefore not likely to "poison."

Considerable attention is paid to the dressing after the operation. The inner bark of a young breadfruit tree beaten until soft, then cut in strips, is applied as a bandage. The dressing must be renewed each morning for two weeks, or until the parts are healed. The patient is not isolated, except of his own accord: but if the operation has been performed by another boy, he is likely to stay away from home until the healing is complete. The boys say that no girl will have intercourse with them unless they are known to have been circumcised, and the girls and women say that an uncircumcised man is filthy and not to be tolerated. No corresponding operation is performed upon the females.

Bruises, cuts, and puncture wounds are treated surgically when they become infected and appear to require "opening." Thorn of orange or lemon or any sharp-pointed implement may be used for this purpose.

Contusions that are greatly discolored are lanced, a shark's tooth being the favorite instrument. A black eye is not regarded as sufficiently serious to require lancing, but contusions resulting in the lameness of any joint are commonly so treated. After the lancing, the regular medicine for contusions is applied (p. 86).

Simple fractures are treated in much the same manner as contusions or bruises, the term *fati* being applied alike to a broken limb and to one lamed by a bruise or contusion. Medical aid, rather than surgical, is sought: a remedy is prepared, part of which is taken internally, part rubbed gently on the affected member. Incidentally, the patient is required to remain as nearly motionless as possible. When movement of any kind is necessary, the patient is lifted or turned by his attendant, with due care not to disturb the injured parts. I saw only one case of broken bones: a little girl broke her upper arm, a simple fracture without displacement. She was treated with the medicine for broken bones (*raau fati*), kept in bed for a week, then kept quiet for another week. Three weeks after the accident she was using the arm as actively as ever.

Compound fractures are said to result in death, without exception. Some are treated as ordinary open wounds, others as simple fractures, with due regard to the stoppage of bleeding. Two cases of compound fracture were described to me. Both were of the femur, and both patients, grown men, died.

Dislocations are reduced quickly, and quite successfully. The accompanying swelling is treated by gently massaging the region of the joint, using *monoi* as a lubricant. I saw a dislocated shoulder reduced within fifteen minutes after the accident that caused it. A companion of the patient

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grasped the arm just below and just above the elbow, flexing it to the utmost. With a copra-sack, folded and placed in the armpit, as fulcrum, the arm was brought forward across the body, and gently forced in various directions until the head of the humerus snapped into place. The upper arm, shoulder, and all adjacent areas were rubbed with *monoi* and massaged at frequent intervals for several days. In three days the patient was able to use the arm moderately; two weeks after the accident he stated that there was no trace of discomfort.

Sprains of ankle or wrist are treated by wrapping the affected member firmly with fibers of *mauu,* a coarse grass noted for its strength. The pain caused by the swelling within the tight binding is endured until circulation is stopped by the pressure, then the fibers are readjusted. This second binding is just tight enough to limit movement of the joint, without actually stopping the circulation. The member is massaged gently at frequent intervals with *monoi* as lubricant. A small boy fell and sprained his left wrist: his mother refused my offer of adhesive tape, and used the *mauu.* The lad howled with pain several times in the course of the next few hours, but his mother refused to loosen the binding. About six hours after the accident, when the hand was beginning to turn black, she removed the *mauu* and gently rubbed hand and forearm until circulation seemed normal, then replaced the binding, being careful to get it just tight enough to limit motion in the wrist and give support without stopping the circulation. The binding was removed several times the following day, and the arm massaged from elbow to finger tips, then again bound. For several days the binding was left in place, without massage after the first two days; then it was removed, and the lad soon had his arm "limbered up" and in active use again. A girl of sixteen sprained her ankle, and had it treated in a similar manner. For two days she did as little walking as possible. Within a week she was walking almost normally, but left the *mauu* in place for over two weeks, massaging the limb from knee to tips of toes several times a day.

OBSTETRICAL PRACTISE

Obstetrical practise in Tubuai is still in a primitive state. There are no midwives. Outsiders are seldom called in to help in any way. The patient's husband and her mother or other near relative are all that are ordinarily required as attendants. No deliveries were witnessed by me but several were described in detail, and the following account is taken from them.

When the time has arrived for the beginning of labor, the patient seats herself on an old mat spread on the floor, or, if the floor is covered with *aretu,* as most of them are in Tubuai, directly upon this floor covering. The male attendant, generally her husband, seats himself directly behind her so that she may rest back in his arms. He is from time to time directed by the patient to massage the region, back, sides or abdomen, where the pains are most acute at the moment. If delivery is difficult, the

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male attendant will sometimes press firmly down on the abdomen of the patient, or knead downward to assist her in the "bearing-down" process. The patient being seated between the outspread legs of this attendant may brace her feet against his heels to assist her in the straining. The female attendant, who sits or kneels before the patient, receives the child, or may, if delivery is slow, assist by manipulating the head of the infant when it has partly emerged. If the infant presents itself in other than the normal way she may attempt to aid delivery by the use of the hands as forceps. Such mishaps are generally fatal to the child and may be also to the patient. It is, however, very exceptional for the delivery to be very difficult, and generally a woman dreads only the first childbirth.

Upon delivery, the infant is wrapped in a cotton blanket if one can be obtained, or, if not, in almost any sort of cloth that is at hand. Until within a very few years, tapa was always used for this purpose, its use continuing long after the introduction of commercial textiles, and not yet entirely abandoned in the neighboring islands of Rurutu and Rimatara. Less attention is paid to the umbilical cord than might be expected: if the placenta is delivered promptly, the cord is cut at a distance of several inches from the infant's navel and tied with a bit of thread or fiber. If delivery of the placenta is delayed, the cord is tied in two places and cut in the intervening space. When the placenta has been delivered, and the cord severed, the infant is bathed, wrapped in fresh cloth if obtainable, and given to the patient to nurse. She will have bathed herself in the meantime, if hemorrhage has ceased, or will have been bathed by the female attendant if she has been unable to do this for herself. It not infrequently happens that the patient bathes herself and the infant as well. The patient wears a pad for a day or two, or for such time as any discharge continues, and if there is pain in the abdomen or pelvic regions she may wrap herself in a *pareu* or binder. Usually a woman is not confined to her home after childbirth; she resumes her regular duties after perhaps only a few hours. One old woman boasted to me of having borne five children "down by the beach," quite without assistance, and without any appreciable interruption of her ordinary occupations.

The placenta and the mat, if one is used, or the grass covering of that part of the floor where the birth took place, are buried at some place not far from the house. I was told that in old times the placenta was buried in some secret place. The umbilical cord, when it detaches itself from the navel of the infant, is either hidden in some out-of-the-way place, or thrown into the lagoon. No reasons were given for the disposal of any of these objects, other than that they must be cared for, lest harm come to the mother or to the child.

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MUSIC

A few harmonicas and accordions, a drum and an antiquated reed organ make up the list of musical instruments seen in Tubuai. The drum, made for a Fourth of July celebration held a number of years ago, suggests the ancient instrument, and is said to be similar to the drums formerly used for the dances.

The songs seemed to be of three classes: *himine,* sacred songs; *ute,* popular songs; and chants. Great interest is taken in the singing; certain persons are regarded as quite talented, having excellent voices and retentive memories. Only the *ute* were heard accompanied by instrumental music—that extracted from harmonicas or accordions.

The *himine* is really a hymn, from which word the term is derived. It is simply a quotation from the Bible, generally very short, sometimes paraphrased, arranged to be sung in parts with considerable repetition. It is customary for the various Protestant churches to hold a general assembly on the first Sunday of each month, for communion services. At these times, and at the Christmas and New Year celebrations, there is competition between the choirs of the different churches. For many of these occasions new *himine* are written, which are generally new only in wording, the music showing little or no change from old standard tunes. Some of these tunes are readily recognized: I remember "Onward, Christian Soldiers," "Lead Kindly Light," and "Love's Old Sweet Song," and several others of secular and nonsecular nature. Many of the tunes are apparently survivals of earlier chants and songs, and are regarded by the natives as antedating the teachings of the missionaries. I was able to record on the phonograph a number of *himine* sung by small groups of the best singers. It is difficult to reproduce satisfactorily the sound of a large number of people singing together, so that these records really give but little idea of the not unpleasant, organ-like sounds of the typical *himine.*

Several *ute* were likewise recorded. Those which have been transcribed show the nature of these songs. (See p. 113.) It was quite impossible for me to understand the words when the songs were in progress; the singers, indulging their humor at my expense, gave me for the most part songs that are of a decidedly obscene nature. It is not fair to the people to assume that all or even the most of the *ute* are of this sort, even though the average Tubuai person tolerates or perhaps enjoys listening to them. Many *ute* are very pleasing lyrics, fairly comparable with the better class of popular songs anywhere; others are folk-songs, dealing with more or less traditional characters. In this class belongs the song or chant of *Pipiri ma* (Star-children). (See p. 113.)

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Very few chants or meles are remembered in Tubuai, and those few are carefully withheld. Each contains information concerning the genealogy of the family to which it belongs, and must therefore be kept secret, lest improper use be made of the information. Probably not more than three or four of these chants are to be obtained in Tubuai.

I was able to do very little with the songs. To properly record and study them requires a fluent command of the language and the complete confidence of the people. A person with perfect command of the language, whom the people regarded as nearly one of themselves, could make available for study an immense amount of the unwritten literature now existing only in the form of these songs.

GAMES

Not until I had been several months in Tubuai was I able to observe children at play; their curiosity was so intense that all would desert their occupation at my approach and flock to see what I might do. My observations are recorded in the following notes which have been revised by Mr. Eugene Doom, who played these games as a boy in Tubuai.

Spinning tops: *te poro ohu* (*poro*, round; *ohu*, spin, whirl). The tops used are very similar to the ordinary peg top but without stem or point other than that of the wood itself. The very young coconut is also used as a top. A string may be used to spin the top, in exactly the manner employed by an American boy, or a whip made by breaking a green *purau* stick in the middle, discarding half and keeping a strip of the bark trailing from the remaining half of the handle.

Kite flying: *e haapee te pauma* (*e haapee*, to cause to fly; *te pauma*, the kite). No kites were seen, but a number of informants say that the kite is in common use by the children at certain times of the year. Apparently, in other lands, there is, or was, a kite season. One reference to kite flying has been found in an old story. For making kites *aati* is said to have been used in former times.

Kicking stilts (*te rore*, the stilt; *e tue rore*, to kick with stilts). School children of both sexes, and the boys up to the age of 25 or so, play this game. It was recently placed under the ban as too dangerous. In playing this game the opponents endeavor to kick the stilts from under each other, or to cause each other to fall in avoiding the kicks. The ordinary stilts give the players about 3 feet of extra height, but some more venturesome and skilled use stilts with the steps 6 or even 7 feet from the ground, "so that the wearer (Teoto, the present Governor) could sit on the school house roof." The length of stilt above the step varied—a short length made the stilt more easily handled in kicking, but called for greater strength of arm because of the lesser leverage. Generally the length was such that the wearer could just comfortably grasp the end by stooping slightly.

Hide and seek: *tapunipuni* (*tapuni*, to conceal one's self). This game is played as in the United States. One person selected by "counting out" hides his eyes, while the rest conceal themselves.

Mumble-peg: *pere patia* (game or play with spear or any sharp instrument). As played in Tubuai mumble-peg differs from the American game only in the substitution of a small imitation fish spear for the knife. The spear shaft, about 8 inches long, is tipped with an orange or lime thorn, and thrown from the back of the hand, the closed fist, and from other positions, the object being to stick the spear point down in the

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ground. The penalty to the least expert player is to extract, with his teeth, a stake driven flush with the ground.

Pere timo. This game is always played on the beach. Two opposing players each scoop out a row of small holes, from five to ten, as agreed; one player takes a seed of *aito* in his hand, then holding it concealed, takes a double handful of sand, and with a sharp downward jerk of his hands, drops some sand successively in each of his row of holes. Into one of the holes he drops also the seed; his opponent must indicate which one. If successful, the opponent plays. If not, the first player repeats his play, first cleaning out all the holes save one; the game is repeated until the guesser succeeds, or until only one hole is left unfilled. At this stage of the game, the double handful of sand is taken as usual and dropped in the one hole, the clasped hands held high above the hole with the query, "*Inia—iraro?*" (up—down). The opponent must guess whether the seed is still in the player's hand or dropped with the sand. If correct, the guesser then plays; if not, the player has won a game. There may, of course, be any number of players, but always in pairs. There is never any betting on this or any other game, of which I have been informed.

Drawing straws. This game has no special native name. Two girls were observed one night at a church song service whiling away the time for nearly two hours, each player in turn holding the straws until the other guessed successfully.

Dolls. I saw only one object that could possibly be called a doll—a rolled up towel placed by a mother in her small daughter's arms, with the command to "run along and tend the baby." After a moment or two the child had the towel unrolled and wrapped about her waist *pareu* fashion. When I questioned the mother she said it was only a device, thought of on the spur of the moment, to get rid of the youngster, who had been annoying her. She confirmed what all my other informants have said, that the Tubuai children do not play with dolls. I had a woman make me some small doll hats, woven of lauhala, to take home as gifts to children, and the idea of bothering with such foolish things amused her immensely. She said somewhat contemptuously that "in Tubuai children do not have to make babies of wood and cloth if they want babies to play with."

Cats-cradles. Only a few persons knew the knack of making cats-cradles, and even they were able to make only a few of the more common Polynesian figures. I learned, however, that in former times many string figures were known, and that for each figure there was a special song or chant, all of which are now forgotten.

Tag and football. The school children play tag, of some sort, but it is generally recognized as a French game, name and all. This same statement applies to football, and to a game known as *pererau* (play with wood or with a stick) in which a short bit of wood is pitched or batted with a stick 3 feet or so in length.

Mention might be made of various games and plays in which the work of the older people is imitated. For example, boys play with small toys like fish spears, tipped with thorns or with short pieces of iron wire. The boys become quite expert, spearing shrimps and small fish, developing their arms and eyes for the more serious business of fishing. They play in canoes on the beach, taking imaginary voyages or standing in the prow, spearing imaginary fish. I have not seen such plays as making mud pies, building toy houses, or making play-gardens. The explanation given by several people questioned was always the same: "Why play, or pretend, when they can have the real thing?" The children do more practical work at earlier ages than do most American children, and it seems probable that this accounts for the relative lack of games.

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LANGUAGE

RELATIONS AND DIALECTS

In the account of Cook's third voyage may be found the statement that "the inhabitants of Toobouai speak Otaheite language." Experience has proved, however, that little dependence may be placed in such statements of early voyagers. At least during the nineteenth century the contact of Tubuai with Tahiti seems to have been closer than that of the other Austral islands, and except in a few minor particulars, the language spoken at present in Tubuai is not different from that of Tahiti. Certain words, for example, *potii* (girl or young woman) that are current in Tahiti are not used in Tubuai. The few words recorded in the following list are supposed locally to belong to the old Tubuai dialect.

Old Tubuaian	Modern Tubuaian (Tahitian)	English
ahi	auahi	fire
heheu	iriti	to open, as the door
mana'o	tatoo	to tattoo
maro	tihere	belt, girdle
ovai	taro	taro
pâ	opani	door
tai	miti	salt, salt water, sea
tutuni	tutui	to kindle; to light
Nahitiorono	Mahu	name of village
Natieva	Taahuaia	name of village
Toerau e toru	Mataura	name of village
Tupuai e hiti	Tupuai	Tubuai, the island
e tahi	ho'e	one
e rua	e piti	two
e ha	e maha	four
e rima	e pae	five
e varu	e va'u	eight

Certain differences were noted between the dialects of Tahitian spoken in Tubuai and in Rurutu. One striking difference is that in Tubuai the consonants *h* and *f* are pronounced very distinctly. In some words either may be used, as elsewhere in Polynesia; in Rurutu the *h* is barely sounded, and generally is used instead of *f;* for example, the word for house in Tubuai is *fare,* in Rurutu *are* (*'are*), with only a slight aspiration to indicate the missing consonant. The following list includes a few of the words that differ in the two dialects:

TUBUAIAN	RURUTUAN	ENGLISH
aati	parure	tapa
aita	aore	no (negative in general)
apoo	rua	hole
aua	pa	barrier, fence
e	a	yes (affirmative in general)
fee	pua'ee	squid
hopu	pa'u	to bathe, to dive
huero	atu	seed, nut

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TUBUAIAN	RURUTUAN	ENGLISH
hupehupe	manuinu	ugly, disgusting
ihu	puta i'u	nose
matari'i	puano	the Pleiades
ma'ue	rere	to fly
menemene	potaataa	round, globular, cylindrical
miti	tai	the sea, salt water, salt, sauce
naonao	ramu	mosquito
nehenehe	i'ei'e	pretty, attractive
nena	era	hat-block
nia	nua	above
omii	arapoa	neck
pape	vai	water, juice
pape haari	niaa	drinking coconut
parahi	no'o (noho)	to dwell, to be seated
pauma	pii	to climb, to ascend
pe	para	ripe
pii	tuo	to call to, to call out
piropiro	pirau	smell, bad odor
pohe	mate	dead
pota	ruau	young taro leaves
puu	pi	unripe, green
rapae	va'o	outside
taoto	moe	to sleep
taviriraa	putoraa	initial corner of mat
taviriraa	iiraa	final corner of mat
to, aeho	ae'o	name of plant
tureirei	utata	to rock or swing to and fro
uouo	teatea	white
uto	uri	sprouted coconut

Marau Taaroa Tera i Farepua, ex-queen of Tahiti, in glancing over these word lists, said that the reason why certain of the old words, still current in some places, are not used in Tubuai is because in Tahiti, when a member of the royal family took or was given a name, any word entering into that name became tapu to the common people. A word with a meaning similar to that of the word placed under tapu was substituted for it; the tapu did not apply to the speech of members of the royal family; they might, if they chose, continue to use the original word. These tapus were observed more generally in Tubuai than in the other Austral islands. Madam Marau cited the following examples:

Ancient Tahitian word; still used in Rurutu.	Name of Tahitian person of rank.	Modern Tahitian word, used also in Tubuai.
moe	Moe Terauri	taoto
noho	Nohoarii	parahi
pa	Pa Arii i Ahurai	aua
pa'u	Tepa'u Arii i Ahurai	hopu
rere	Teriirere i Tooarai	ma'ue
vai	Terii Vaitua	pape

Many of the songs contain words the meaning of which is not now known. Some such words are presumably old forms; others merely those that have become so distorted, in the long life of the songs in which they

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occur, that they have quite lost their identity, and are only meaningless combinations of sound. A careful study of the old songs would yield much philological information not to be obtained in any other way.

SIGNIFICANCE OF NAMES

It is obvious that a comparative study of the Polynesian dialects will do much to reveal the past history of the people. With this idea in mind I began a systematic collection of names of different classes of things. This work was given additional impetus by the suggestion of Mr. E. W. Gifford that a list of place names be collected wherever possible. The lists do not include the names of the various fishing grounds inside and outside of the barrier reef, of the points of land jutting into the lagoon, of many of the streams and swampy places nor of various minor classes of things. The Polynesian is very liberal with his names, and a collection of an extensive series of lists would show an astonishingly wide vocabulary. The coconut bears a different name in each stage of development. A young fish probably does not bear the same name as a mature fish of the same species. And so it is with many classes of things. These terms have a tendency to remain unchanged through long periods of time: people are inclined to name places and things found in a new land in accordance with a resemblance, identification, or perhaps only in commemoration of some place or thing they were familiar with in their former habitat.

PERSONAL NAMES

An individual in Tubuai may be known in his own community by any one of several names. He may have one name officially recorded; his parents may refer to him by a second name and address him by a third; and the name given an investigator may be any one of these or of several others. The result is that great confusion exists in the official records, the census returns do not always correspond with the land title records and the resident French gendarme declares, with utmost sincerity, that the people do not know their own names. As a matter of fact, the people do know their own names, and can generally account for each name they bear.

At birth, a child is given one or more names by his parents and various friends and relatives. One of these names is selected for the registration of the birth required by law, thereby establishing the name as legal. At baptism, which takes place within two or three months in the Protestant and Catholic churches, and at the age of eight in the Mormon Church, a name is given the child, generally the legal name, almost always one of the names given at birth, but sometimes an entirely new name. Thus a child has a legal name, a baptismal name, and probably several others that were

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given at the time of his birth, some of which may be identical. In addition, a child generally has what is known as a calling name, to which he answers just as an American child answers to his nickname.

The next names are given at marriage. The father or the parents of the bride bestow a name, sometimes two or three names, upon the groom, and similarly the father or parents of the groom favor the bride. It has become customary in Tubuai to give the same name to bride and groom, differentiating by the addition of *vahine* to the name of the bride, and *tane* to the name of the groom. Thus when Tehinatemaverani married Tautahi, her name became Rei Vahine and her husband's name became Rei Tane. These new names became the ones customarily used, but I noticed that for many months the parents of the youthful couple found it difficult to accustom themselves to the new names.

If a couple live together without the formality of marriage, no names are taken by either party. Not over half the couples in Tubuai are married. If a couple separate, they may retain their married names or not, as they choose. If a person marries after the death of wife or husband, new names are taken. One person married three times had assumed three successive married names, dropping each time the previous name.

A custom now almost disregarded, but formerly universally observed, is the taking of a name in commemoration of the death of some person near or dear to one. A mother will take a new name if one of her children dies; thus Tuateia took the name of Teurunatahuhu when her child died, but later when one of her grandchildren died she took the name of Mootua Vahine. It was formerly the custom to take a name suggested by some incident connected with the illness or death of the person commemorated. Thus "Ruitoru" implies that death took place on the third night of the illness; "Maoro" suggests the lingering illness of the deceased; "Peapea" means trouble. One old man is commonly known as Tuahine (Sister), a name given him in his boyhood in memory of a dead sister.

Thus the average adult in Tubuai has a number of names, including one legal name, which may or may not be also the baptismal name, a name given at marriage if the person be married, and possibly a name commemorating a dead person. To identify a person beyond question it is necessary to procure the legal name and as many as possible of the other names.

Many personal names give no hint as to sex. Such names as Terii, Tetua, Teupoo, and many others, may refer to men quite as readily as to women. Certain others, however, are distinctive. Araia, Hina, and Taiho, common names in Tubuai, always refer to women; Tautu, Taaroa, and Marama always refer to men. Some of these names were originally of mythical or legendary characters, and preserve the sex concomitant in their

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modern applications. Thus Hina was the first woman; Taaroa (Tangaroa) was one of the deities. Still other names are recognizable as Tahitian renderings of English or other foreign names. Mere, for Mercedes, or for Mary, and Tioni or Tihoni for John are examples. These names, of course, are applied to males or females according to the application of the originals.

The endless number of descriptive names, including besides others practically all the names taken in commemoration of death or illness, seem to have no sex limitations. Ruitoru, meaning three nights or the third night, might refer to either a man or a woman. It is probable that a thorough knowledge of the language would make possible recognition of a number of names as belonging to one or the other sex, but it is my impression that the people themselves do not in general consider names as including a suggestion of the sex of the persons named.

A comparison of lists of Tubuai names with a list of over 600 names, included in the official census of Raivavae for 1918, shows that only 60 are common to the two islands. This is a low and certainly faulty figure, as the lists are not properly comparable: the Tubuai lists include all classes of names, and the Raivavae list only the legal, registered names. But even so it is suggestive, and is in line with other evidence. The name Araia, borne by a dozen or more Tubuai females, appears only twice in the Raivavae census list. Other names, common in one island, are relatively rare in others. It seems that most of the names are of wide distribution, but that some are peculiar to certain islands. It may be that certain names are peculiar not only to one island, but to one family, but evidence of this is difficult to ascertain as practically every one in Tubuai is related more or less with everyone else. A study of old genealogies might settle this point and shed light on the distribution of the progenitors of the present inhabitants of the islands.

Place Names

The names in the following list refer to tracts of land except those marked I, islet in lagoon or on the reef; M, mountain peak; P, pass through the reef; S, stream. It is said that the island of Tubuai takes its name from the tract of land called Tupuaiehitu (Tupuai-e-hitu).

Ahoa	Haamau	Hapuu
Ahotea	Haapahono	Haramea
Aira	Haapuatua	Hareau(a)ti
Ana	Haaripae	Haremaa
Anua	Haatau	Harepua
Aore	Haena	Hareraau
Apaura	Hamore	Haretapu
Atiahara	Hanareho (M)	Harii
Auohiro (S)	Hanaroa	Hariitaata
Farani	Hanatahi	Hauehu
Haaa	Hapopo	Haumainua

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Haupea
Haura
Haurii
Hautara
Hautara (S)
Hauvaa
Herani (M)
Hiamoora
Hitipereue
Hitiura
Hoopua
Hoopuaa
Hooura
Horomatani
Huamori
Hueava
Hutumaru
Huuveru
Iiorere
Mahihi
Manana
Manono
Mao (Ma'o)
Maramaura
Marana
Mareura (M)
Mareretiua
Maruhau
Maruoi
Marutua
Mataiau
Matairani
Matanao
Mataorono
Matapara
Matarau
Mataura
Maunaraha
Maunehitua
Mihiura
Mititapu
Moa
Moana
Moemoe
Moerai
Motiha (I)
Moofara
Motohara
Murivai
Nahaueha
Nahinaupea
Narirani
Natimati (M)
Nihomano
Nihomanu (?)
Nuuriro
Ofai (I)
Ohoro
Oio
Onereva
Oparu
Orepo
Oroa
Otava
Pae
Paepaeohiu
Paepaetutae
Pahatu
Pahatu (M)
Pahuhuna
Panaihara
Panaru
Panee (M)
Panautoa
Papavahie
Paratea
Parepareaura
Parioopu
Patupatu
Peetau
Peeura
Peheue
Piritie (M)
Potuitui
Poutoa
Potu
Puahi
Puainoho
Punanoe
Purepo
Putaura
Puturani (M)
Puuketua (M)
Raahia
Ranitatau
Rarouru
Rautaro (I)
Renui
Ruapou
Ruatara
Taahuaia
Taamora
Taerepa
Tahihi
Tahiriura
Tahuhu
Taiariari
Taihau
Taimate
Taitaa (M)
Tamatea
Tamauu
Tanetepu
Tanitoa
Taoa
Taonetera
Taova
Tapapatauai (I)
Tapuata
Taputaputea
Taraouvo
Tarahu
Tareiau
Tarenavaha
Taronoahoe
Tarotapu
Tarotu
Tarutepua
Tauranaivi
Tauruaura
Tautee
Taruroa
Taupa
Taurea (M)
Tavaetu (M)
Teaeva
Teahoteuira
Teahutapu
Teana
Teanapoiri
Tearaea
Tearahaiti
Tearaiteoi
Tearapapa
Teavaanamoana (P)
Teavahavai
Teavahue (P)
Teavarautaro (P)
Tefaatau
Tehaapu
Tehano
Tehaputaai
Teharateovi
Teharaura
Tehatu
Tehauhanahuru
Tehauaniao
Tehauaraia
Tehauhuaai
Tehauhuahine
Tehaunahanarii
Tehauniau
Tehauohoto
Tehauonere
Tehauopeva
Tehaupuahi
Tehautahia
Tehautahu
Tehautapaau
Tehautareni
Tehautootoo
Tehititaau
Temae
Temanaha
Temarere
Temarutorea (M)
Temaui
Temauu
Temiromiro
Temuhu
Teofai
Teonemarua
Teoneo

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Teopua
Tepairu
Tepapa
Tepao(u)a
Teparehau
Tepeau
Teraotahi
Terautipara
Tereva
Teroitaihau
Teruaotuu
Teruaitemuri
Teruihatu
Tetairama
Tetararea
Tetiare
Tetoonea
Tetoropu
Tetuarona
Teuo
Teupoo Tehaarua
Teuruohina
Tevahavai
Tevarovaro
Tevavai
Toena (I)
Toero
Torea
Tuaaa
Tuanahi
Tuanai
Tuarani
Tuatua
Tuituaroa
Tumarotai
Tunarutu (M)
Tuoro
Tuporo
Tupuaiehitu
Tutaemoa
Tutava
Tuturipohatu
Uruhau
Vahiavae
Vahoro
Vaia
Vaiapu (S)
Vainono (known also as Taoaaho)
Vaioopu
Vaiovau
Vaipua
Vaipuaa
Vairoto
Vaitauarii
Vairani
Vairavai
Vairearea
Vairua
Vaitoaha
Vaitomoana
Vivi

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FOLK TALES

CLASSES

In Tubuai and in Tahiti I found it possible to obtain some fragmentary mythological material and several fairly complete tales. At first I was obliged to record this material phonetically without any very clear idea of its meaning. Later when my better knowledge of the language permitted me to do so, I translated the tales and tried to get more complete versions, also other tales to add to the collection. It was discouraging to find, however, an extreme reluctance on the part of most of the people, to admit knowledge of any such un-Christian things as myths or folk-tales. Almost anyone could recite Psalms or long passages of Scripture, but few could or would tell me of what must have been common knowledge before the introduction of the Bible a scant hundred years ago.

Myths of creation and of the deluge were not obtained in even the most fragmentary form. Repeated attempts to get such tales met either with utter failure, or with ready reply in the form of the Biblical account. Although many such tales were told me, none deviated sufficiently from the Old Testament version to give the slightest hint that any form of origin or deluge myth was known prior to the advent of Christian missionaries.

When I asked definite questions concerning the old Polynesian deities, or the void or darkness or mist from which the present earth was formed, the informants denied all knowledge on such subjects. I was repeatedly told that in Raivavae there were people who could tell me all about such matters. It is my impression that some of the older people in Tubuai remember more or less clearly some of the old cosmogonic myths, but that they are either ashamed of such things, or afraid to admit the knowledge because of modern religious feeling.

The deity now considered as the Creator is the God of the Old Testament. That such has not always been the belief in the Austral Islands is indicated by the wooden image of the creative god, illustrated by Brigham (7, figs. 237-238) which came originally from Rurutu and is now preserved in the British Museum. When described to people in Tubuai and Rurutu it roused only slight interest, and evoked the comment that such things belonged to the heathen times, and had best not be thought of by modern people.

There are still to be obtained genealogical tables, in which the ancestry of existing persons is traced back to gods. One such table related to me traces descent from a certain god, but the ancestors, beginning with the fifth generation preceding that of the informant, and including all from that generation back to the god, were natives of Tahiti. A second table stops short of the major gods, but includes reference to the fact that the

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earliest named ancestors were descended from patron dieties of certain maraes. It may be added that these gods, in these two genealogical tables, are by their present-day descendants ostensibly regarded as mere names. Careful questioning did not yield a single item of information as to their nature, powers, or origin.

It was extremely difficult to persuade the Tubuai people to relate these genealogical tables, as they are closely connected with modern land titles, the French having accepted fluent knowledge of a genealogical table as legal evidence that the person concerned must be a member of the family involved. However, the fact that the only two tables I obtained involved descent from greater or lesser gods indicates the former belief in an evolutionary or genealogical cosmogony.

The demigod Maui was not unknown in Tubuai. The following account was given:

> Maui was a great *tahua,* or kahuna, who came down from the north, from or through the Tuamotu Islands, to Raivavae, where he built a great marae. Bringing with him a stone from that marae, he came next to Tubuai, where he built a marae which some identify with the marae Tonofai, near Mataura, on the north side of the island. Taking with him each time a stone from the marae just built, he went from Tubuai to Rurutu, then to Rimatara, building a marae on each island. From Rimatara he went on, some say to the Cook Islands, some say back to his home north of Tubuai, some say to Havaii-i-te-Po, the underworld.

The information relative to the building of the marae by Maui was obtained from Tautu-a-Mauritera, of Tubuai; other informants stated that Hiro, not Maui, built these maraes. There is considerable confusion in Tubuai as to the identity of these two characters. I give emphasis to the version in which Maui built the marae only because in general Tautu-a-Mauritera was a thoroughly reliable informant.

There seem to be no standardized myths regarding the exploits of either Hiro or Maui, but scraps of information indicate a previous general knowledge of some of their deeds and characteristics. Throughout, the two names seem practically interchangeable. For example, on one occasion a man with whom I was fishing used a barbless hook. In answer to my comment on the lack of the barb, he replied, "If Maui had been more crafty, perhaps he would have thought of the barb. As it is, we have always made our hooks without barbs, and manage, at that, to catch plenty of fish." Inquiry brought out a few words about Maui, showing the old man's faint remembrance of the exploit of fishing up the land. He did not, however, remember any details as to the location of the land brought up from the sea, nor any of the attendant circumstances. Neither did he respond to suggestions regarding Maui's snaring of the sun.

The fire-quest, on the other hand, was recalled by Toma, of Mataura,

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who showed me the use of the fire plow (p. 41). For his hearth he selected a piece of hau, and for the plow a smaller stick of the same material. I asked why he selected the hau. After some hesitation he replied that Maui had hidden the fire in a paddle made of hau, when he first secured fire for his relatives. When pressed for further details the old man remembered only that Maui had gone somewhere, perhaps, he said, to Havaii-i-te-Po, and brought back the fire, and that in order to save his canoe, which the carelessly disposed element threatened to destroy, he had placed a little fire within his paddle, and extinguished the rest. So that to this day a man out in his canoe may obtain fire from his paddle, and the wood used when on shore is preferably the hau, of which Maui had made his paddle. No other versions of this myth were obtained, and when upon another occasion this informant was induced to repeat the story, he gave no additional information.

Closely associated with the Maui cycle is the story of Hina and the bird Rupe, her brother. (See p. 108.) This story in the Tubuai version follows closely the New Zealand version as recorded by White (52, vol. 2, p. 112). The names of the principal characters, Hina, Rupe, and Tinirau, are identical, and the fundamental plot of each version the same: Hina marries Tinirau, goes with him to a distant country, where she is illtreated by her husband; Rupe goes to her assistance and carries her and her infant away to a place of safety. No mention is made, however, in the Tubuai version of the relationship of Rupe or Hina to Maui, or of the name of the island home of Tinirau. On the other hand, the killing of all the people of Tinirau by Rupe is an incident found, so far as I have been able to learn, only in the Tubuai version.

In one version of the Maori tale (52, vol. 2, p. 142) Tinirau surrounds the house, in which he has placed Hina, with a protective hedge or barrier of interlaced brambles and vines. The Tubuai version has the house wrapped about, both sides and top, with a net. In this connection it is interesting to note that there are now no homemade nets used in Tubuai, and I was informed that none had been made for a great many years.

Tales of cannibals are not common in Polynesian mythology, yet one is well known in Tubuai. This tale, that of the cannibal woman Hina who lived in a cave high up on a mountain in Rurutu (p. 109), may be related in some manner to the Maori tale of Whaitari, the cannibal woman who used to come down from the sky to catch humans, and carry them back to be eaten (52, vol. 1, p. 179). In the Maori tale the cannibal woman uses a net to catch her victims; in the Tubuai tale a net is used finally to catch the cannibal woman.

Related to tales of cannibals and possibly directly related to the tale of the cannibal woman of Rurutu, is the story of the savage woman of Tubuai, who

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killed newborn children, and herself met death as the result of attempting the life of a craftier woman (p. 110). The goddess having most to do with childbirth, in Polynesian mythology, is Hina. It so happens that the name of the crafty woman at whose hands the savage woman of Tubuai met her death, was named Hina. The occurrence of the name Hina in a tale the principal character of which causes childbirth, even though she then kills the newborn infant, suggests the possibility that through some confusion there have become associated incidents referring to Hina, the goddess of childbirth, with other incidents referring to some savage or cannibal character. This idea gains weight when it is considered that a second fragmentary version of this same tale gives Hina as the name of the savage woman.

No tales built on the swan-maiden theme, the descent into Hades or Orpheus theme, or the stretching theme, were recorded. When, as an experiment, I related a tale of the Orpheus type, the listeners scoffed at the idea, and declared that only an *etene* (heathen) would believe such nonsense; they themselves knew quite well that no one had ever gone to the underworld and returned.

Tales of a quasi-historical nature were recorded from both Tubuai and Raivavae. That they are well known is proven by the frequency with which I met the heroes of these tales while collecting mythological data. Tematauira, the Tubuai character, was evidently a local culture hero, and his visit to Rurutu, upon which occasion he met defeat and death at the hands of Ututoa, the hero of Rurutu, was described by a number of informants. The clearing of taro patches by night, the building of a great canoe, and the ability of Tematauira to carry great loads without assistance, together with his extraordinary physical development and his cunning as a liar, were the elements that had the strongest appeal. The tale of the death of Tematauira was given me by one informant, who declared that she has often climbed in the very *mape* tree beneath which the hero had met his fate. (See p. 111.)

The tale of the battle between the two Tubuai factions in which the people of Temarere were exterminated by Tematauira assisted by the Borabora hero, Haatauhi, was told in less complete form by several informants. Incidents from the more complete version were known to many, who said that the stones which the rivals threw in their trials of strength may still be seen on the slope of Mount Hanareho. It may be noted that the names Tematauira and Temarere are parts of the names of several living Tubuai people.

Other heroes, remembered as such, but about whom no tales were told, are Mahurani, of Tubuai; Taioaia and Ruapaauri of Rurutu; and Haatauhi of Raiatea, who evidently is identical with Haatauhi of Borabora.

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A single astronomical myth was recorded, the tale of the two children who became stars. Their names were given by one informant as Pipiri and Tapiri, collectively known as Pipirima. Other informants said this was incorrect, and that they should be known simply as Pipirima. A Rurutu informant gave them the name Pipinima. The tale is very old and is well known throughout the Austral and Society islands. It has been recorded before, a version appearing under the word *anianu* in the Tahitian Dictionary, which gives the name of one child, the boy, as Pipiri, and of the other, a girl, Rehia, a name not known in Tubuai. The incidents of the tale are, however, quite similar. In Tubuai, and in Rurutu, the tale begins with a prologue recited in a monotone, telling the actions that culminate in the flight of the children to the ridgepole of the house. The remainder of the tale is always chanted.

The Rurutu tale of Taie is included (p. 114) not because I believe it to be very old or related to tales of the ancient times, but rather to show what an enquirer is likely to get at the present time in response to request for *aamu* (tales).

The mythological material from Tubuai is thus seen to be fragmentary and hardly sufficiently extensive to serve as basis for any definite conclusions. Yet it is evident that in former times certain of the widespread Polynesian tales were well known in Tubuai. The Maui cycle is represented; the ideas of gods and heroes, of other worlds below the sea and above the earth, of cannibals and evil spirits, all were developed or survived from development elsewhere.

From any considerable mass of mythological material a surprisingly complete picture may be drawn of the culture of the people, particularly of the items characteristic of their older and perhaps otherwise forgotten culture. The older tales preserve to a remarkable degree their integrity, despite modern influences. The idea of reconstruction of the culture of a people from their mythology is by no means new; it has been successfully tried by Cole (14) and others in various fields.

ANALYSIS

Based on a study of the very small collection of mythological material from the Austral Islands, the following presentation of the ancient culture of Tubuai and neighboring islands has been prepared:

Physical characteristics of the country:
- Islands, with outlying reefs, and mountainous interior.
- Islets on the reef.
- Valleys, at whose mouths, near the seashore, the people were generally to be found.
- Land in general covered with undergrowth.

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Water holes, from which drinking water was obtained, and in which the people bathed.

Trees, including the *mape*, the *ati*, the *haari* or *niau*.

Islands known: Tubuai, Raivavae, Rurutu, Borabora, Raiatea, Tuamotus.

Food:

Taro, breadfruit, bananas, fish, shell-fish.

Food preparations, for voyagers: *tiromi; popoi.*

Method of cooking: in the umu; fish and shell-fish might be eaten raw; *popoi* and *tiromi* were prepared from taro.

Methods of catching fish: spearing at night, with the aid of torches; catching with hand lines or spears while walking along the reef in daylight; casting nets small enough to be handled by one man without assistance.

Cultivation of food plants: land cleared for taro patches.

Shelter:

Houses built with floors; some of them elevated above surroundings; more than one door; the roof with a ridgepole; furnishings include *aretu* (a variety of grass) spread thickly on the floor, and mats. Each house has its umu.

Clothing:

Nowhere mentioned.

Household implements and utensils:

Gourds for seawater and coconut bottles for fresh water.

Transportation:

Canoes and ships, in which voyages could be made from Tubuai to Rurutu, and from the Tuamotu Islands to Raivavae. Other voyages from Tubuai are mentioned, but in one tale no canoe is mentioned, in another the voyager flew.

Religion:

There were maraes, specific mention being made of Marae Peetau, in Tubuai and of Marae Mahara, at Haariroutu, Raivavae, called also the Marae of the son of Mato.

Whales sacrificed upon the marae, cut up and eaten after being cooked in or near the marae at Mahara, the bones hung on the walls of the marae as decoration.

Prayers were offered by the parent of lost children.

Social organization:

Districts of Tubuai separately organized, and at times at war with each other.

Chiefs or kings not necessarily the greatest warriors or heroes, as in Rurutu the king or chief was Temaevaarii, the hero or great warrior to whom the people appealed to drive out an invader was Ututoa. There were lesser chiefs, or citizens (*huiraatira*).

Man's work included clearing of land for taro patches; canoe-building; fishing.

A chief or king placed a kapu upon his daughter; anyone attempting to take that woman was to be killed; nevertheless she eloped with her suitor, who came by stealth, enticed her outside her father's house, then carried her away on his ship.

A young and attractive woman from a different country had many suitors. She accepted only one of these, dwelt with him and bore him many children. He and the children were grief-stricken when she finally left them to return to visit her relatives.

The first-born child was esteemed above the others.

Children were adopted, and adopted children having the same foster-parents considered themselves brother and sister as though related by blood.

It is obvious that many topics not included in this tabulation might be included were the body of mythological material greater, and the topics which are noted might be quite materially expanded and modified.

It would be folly to attempt study of grammatical forms from the

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mythological material collected in Tubuai, but a close comparison of the various tales brings out numerous linguistic points, in spite of the inaccuracy of the recording and the poor quality of the actual material. For instance, the Rurutuan words *noho, nua, mate,* occur in tales by Rurutuan informants, whereas the Tubuaian (modern Tahitian) words *parahi, nia,* and *pohe,* having the same meanings, occur in the Tubuai tales.

I did not attempt the serious study of the Tahitian language as spoken in Tubuai beyond the point necessary to give me reasonable ease in communicating with the people. I have therefore omitted the original versions of the tales, and give, in the following pages, only the English translations. In making these translations I was greatly assisted by Mr. Eugene Doom, of Tubuai, whose command of the native language is perfect, and whose English and French are excellent. Dr. Droillet, the government interpreter in Tahiti, very kindly checked the translation of two of the tales, and Araiatehere, of Rurutu, paraphrased some of the difficult Tahitian passages and thus made possible their translation.

HINA AND THE BIRD RUPE

The following story was related to me by Mr. Eugene Doom:

A certain person adopted a girl named Hina, and a bird named Rupe. This was a male bird. Thus Hina became the sister of this bird, and this bird became the brother of Hina, because they had the same adopted parent.

And when they were grown, their foster parent died, and they lived on without a parent. One day Hina was taken to wife by a certain person named Tinirau, and taken to his distant country. He left Hina there, and he, Tinirau, went to another place. And Tinirau told his people to take good care of Hina, because she was pregnant; therefore they placed Hina in a house, and made a net, which they wrapped about the house, and over the top as well, so that neither might Hina go outside, nor any enemy go inside and do her harm.

Hina lived on there in the house, she alone, and there came the day of her labor; she moaned in pain. But not a single person came to help her. And then she thought of her brother, the bird Rupe, in the distant country, and then Hina called, "Rupe, Rupe, Rupe, come here, help me!"

And it was not long before there was a noise up on the house, and the bird called [to her], "Hina, here I am."

Then Hina said to him, "Come here and help me, in my travail." And that bird attempted to go inside, but it was not practicable, because the house was wrapped in the net. Then the bird attempted to make a hole, that he might thrust his wing inside. When the hole was completed, Hina called out, "Rupe, here in my back is the pain." This bird clasped his wing about the back of Hina, and after a while Hina again called out, "Rupe, here in the front of my body is the pain." This bird then clasped his wing about the abdomen of Hina, and Hina gave birth to a boy. And thus in spite of all this bird took the best of care of Hina.

Tinirau came there, and just upon his arrival Hina gave birth. So Hina said to her bird, "Carry me back to our country, where we were reared. And here is my wish: transport the people of my husband, of Tinirau, first, and when finished, transport me also."

This bird said, "That I can readily do: I shall transport them upon my back and wings."

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And the people of Tinirau came thither and up on the back and wings of this bird. The bird flew, and when he came to the ocean, the bird shook them down into the sea; all the people were killed. The bird returned to Hina. Hina inquired of him, "Where are the people of my husband, of Tinirau?"

The bird replied to her, "You need not be troubled; they have arrived at our country." The bird transported the other people of Tinirau, and cast them down into the sea, and all were killed. Three times thus did the bird, until all the people of Tinirau had been killed.

Then also the bird transported Hina, and when they came to the ocean, Hina saw floating there the bodies of the people of Tinirau, dead. Hina therefore asked this bird, "Why have you killed the people of my husband, of Tinirau?"

The bird replied, "Because they did wrong to you, while you were living [lit. in your living] in the land of Tinirau. They encircled you in a net, and they did not help you in your labor. Therefore I was angry with them, and I killed them all." It is finished.

HINA, THE RURUTU WOMAN

The following story was told by Teata of Rurutu, in Tahiti:

There lived in Rurutu a woman, a cannibal woman, in the ancient times. She lived up on the mountain Manureva; her dwelling-place was not known to anyone. She lived upon the mountain in a cave in a very high place. Her work was weaving mats, in her cave at night.

She used to go down to the seaside to lie in wait for people, at the lower ends of the valleys. When she found people she killed them with her finger nails. When they were dead, she roasted them. When cooked, they were eaten by her. When daylight come, she was frightened and hid in her cave. When noon time came, and all the people slept, she went, she went seeking, she went looking for people at the seaside in the valleys.

It happened one day that three sons of a person of Avera were lost, the children of the chief of Avera. The father went and looked for his three children, but they were not to be found. The father returned to his house. The father mourned for his children, because they had not been found. The father prayed to God. Next day, the father went to search again for his children, but those children were not to be found. The three children had been carried by this woman up onto the high mountain.

Hina killed two of the children, and she left the other boy; she ate the two children and thrust the other boy into the pen. Thus this boy was spared. One day this boy was up on the mountain, at noontime, and that woman went down to the seaside to seek firewood, to roast that boy. The boy was afraid of that woman. She returned to her cave, but the boy was not there; he had run away down to the seaside to his father. Hina was angry, at being without her food; it had run away; Hina sought this boy, but he was not to be found. Down at the seaside was this boy with his father.

He told his father that the other two boys had been done away with by Hina. That father went in search of the evil woman, but she was not found. The father was told by this boy that those other two children were no more, having been eaten by Hina.

One night a boat put out to sea. They saw the light of Hina on the mountain. At daylight their boat went ashore, and these people told those on shore they had discovered that woman by the burning of her light the previous night up on the mountain, Manureva. Another day they went and made a net to catch that evil woman. They worked until their net was finished.

One day a great many people went up the mountain; some of the people went up from below to cast the net; one boy went up to the very cave of Hina, and this boy

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showed the people the dwelling place of Hina upon the mountain. The people came and seized Hina, catching her in their net. She was carried down to the city; this evil woman was struck down, was killed, was quite dead. Never again did she eat the people of Rurutu. It is finished.

TETAOHAMAI, A SAVAGE WOMAN OF TUBUAI

For the following story I am indebted to Mr. Eugene Doom:

There lived in Tubuai in Teruaotera[2] a certain savage woman, Tetaohamai by name, a very evil woman, whose occupation was killing people. When a woman was in travail of childbirth, she went and caused the birth, and when the child was delivered, she killed it, by strangling it by the neck. Very frequently she did this; no matter how great the distance, if she heard of a woman in travail she went directly there. She seized and killed very many children in all the villages.

After a while it was known by all the people that this woman was killing the newborn children. And one day, this savage woman decided she would kill Hina, also, a certain wise old woman of Huahine. She said to Hina that they should bathe in the stream at Tevaipera. And they went to bathe. And Hina also took her coconut water-bottle, and when they arrived at the water-hole, Tetaohamai said to Hina, "You go first, down into the water."

Hina replied, "You go first, I will fill my bottle with water." They disputed, and after a while, Tetaohamai went down into the water. Hina then said to her, "Plunge down under the water." Tetaohamai plunged down, and at the third of her plunges, the water-bottle of Hina was filled with water, and when Tetaohamai came to the surface, her head was struck by Hina with the coconut water-bottle, so that she was killed. It is finished.

TEMATAUIRA AND UTUTOA

The following story was related to me by Mr. Eugene Doom and by Tautu a Mauritera:

There was born here in Tubuai a person, Tematauira by name, of the woman Tinauri[3] of Ahoa, and he was stolen by a certain person of Paorani. He was taken to Paorani and adopted, because this person of Paorani knew Tematauira would become a very powerful man when grown.

When Tematauira was partially grown, he cleared taro patches at night, and he completely finished the clearing of a taro patch in a single night, and in the morning the people saw the taro patch completely cleared. And the place where he threw the brush he cleared away was not to be seen, so far away did he throw it.

Later on, when Tematauira was fully grown, a great canoe was made by him and his people, and when it was finished, he went to Rurutu in that canoe, with two other persons, they three together. They landed at the village, Auti. Their canoe did not land; Tematauira stepped down into the sea, and went ashore, and the people of Auti were greatly surprised by the sight of Tematauira, because he was a very tall man: his height was five fathoms.

He was well received by the citizens of Auti, and they made four hundred bundles of *popoi*, and gave them to Tematauira and his people. Tematauira himself carried them aboard their canoe, two hundred in one hand, two hundred in the other hand. And Tematauira lied to the people of Auti, [saying] that they would return here to Tubuai.

[2] Te-rua-o-te-ra, literally, the hole of the sun. My informant was unable to say whether this name referred to a particular place in Tubuai, or to the "cave of the sun," whence, according to widespread Polynesian tradition, the sun emerges every morning.

[3] Tinauri is probably a contraction of Te Hinauri. Hina, who is an important figure in much Polynesian mythology, is also known as Hinauri. Other versions of this story state that Tematauira was the son of Hina.

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And that same night they went to the other side, and at daylight they arrived at the village in Avera. Tematauira went ashore, and that time he killed five hundred people. The hero of Rurutu, Ututoa by name, was brought, and came to kill Tematauira. When Ututoa arrived they fought each other. They thrust with spears, but Tematauira was not injured. Ututoa saw clearly that not by such means would Tematauira be killed by him. So he went and inquired of his mother, what should be the method of killing Tematauira.

His mother told him the way: "You go and dig a hole, and when its depth is up to the neck of Tematauira, make a noose of sennit on top of the hole, and cover the hole with coconut leaves. Provoke Tematauira to anger, and when he arrives on top of it, and he falls down into the hole, jerk tight the noose of sennit, and catch him by the throat. This shall be the means of his death."

Ututoa went and told the people all the instructions he had received from his mother. The people of Avera went and dug a hole, and covered it with coconut leaves, and made a noose of sennit, and led the end of the noose of sennit up into a *mape* tree. And they provoked Tematauira, and when he came to the top of the hole, he fell in, and the noose of sennit was drawn tight and it caught his throat securely. And Tematauira struggled, and the noose of sennit was very nearly broken: one strand remained to be broken when Tematauira was speared to death. It is finished.

TEMATAUIRA

The story of Tematauira was recited to me by Tautu a Mauritera.

[There was] a certain person, Tematauira, in the ancient times. Here is that which he did, in the beginning, here in Tubuai: he prepared taro patches; he did not work in the daytime, when night came, he went and worked at night. In three nights that taro patch was cleared by him.

Here is the second of his deeds: he went and built a ship in Tubuai. He commenced cutting the timbers for that ship, *ati* was the timber he cut, five hundred timbers were secured by him in a single day. And he began building that ship, and in three months that ship was completed. And he commenced to journey to Rurutu at one o'clock in the morning, and arrived at ten o'clock in the evening at Auti, and he went ashore to the feasting. And they ate, all of them, that food. And when satisfied, they remained in the village that evening. They argued together, they and the hero of Rurutu, "How many *popoi* for you, Tematauira?" (E hia rau popoi e marea ia oe, e Tamatauira e?)[4]

Then replied Tematauira, "One hundred *popoi,* one hundred *tiromi* [preparations of taro]." Tematauira himself took his bundles, carried them aboard the ship and departed.

The third of his deeds: He went to the village of Avera. He stepped down into the sea. The citizens saw him approaching upon the submerged coral. "I shall go and spear them, with my spear." The people were killed by him. These are the people killed by him: five thousand. And there came a certain woman and brought Ututoa, to come and fight Tematauira. Then said Tematauira, "E po ara aria na tei na uri."

Ututoa replied to him, "Ututoa!"

Then they battled there in the sea, and on up to the dry land. Ututoa ran to his mother, and inquired of her, by what means Tematauira might be killed. "You dig a deep hole beneath the *mape* tree. Take some sennit to snare Tematauira; place it over the hole; make a snare, and lead it up into the *mape* tree; jerk it tight and he will be killed by you; there can be no other way by which he may be killed by you." Thus did Ututoa, and Tematauira died there in Rurutu. The ship was given to the chief

[4] I have been unable to translate this question exactly, as the precise meaning of the Tahitian phrase *e marea* is not clear to me. The general idea is, however, obvious.

[5] The meaning of the quotation is not evident to me. It apparently is anything but complimentary, as the epithet used *uri* (dog) is about the strongest that can be used by the Tahitian.

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by Ututoa; the citizens were greatly pleased with their splendid ship, received by the chief from Ututoa, in the ancient times in Rurutu. An excellent chief was this chief, Teuru the Second. This was his name: Temaevaarii. It is finished.

TEMATAUIRA AND HAATAUHI

The story of Tematauira and Haatahi was related by Mr. Eugene Doom:

There lived in Tubuai a certain heroic person, Tematauira by name, and he thought he would kill and exterminate the group of people called Temarere. They had grown to be very numerous, and therefore this hero Tematauira realized clearly that not by him alone could that nation of people, Temarere, be disposed of, because they were a very great host. Therefore he sent word to a certain heroic person of Borabora, of Teraitua, no other than Haatauhi, to come here to Tubuai and help him in the killing of the nation, Temarere.

Thus one day there arrived here in Tubuai that hero, Haatauhi. He landed on the beach at a certain place, a marae called Peetau, and he was overcome by sleep there on the beach in the midst of the *pohue* bushes, his *parani* close by his side. It is said that eighty people together were required to lift his *parani* [a sort of war-club of ancient times]. And thus Haatauhi slept in his sleeping place, being very tired from his flying here from Borabora.

There came down a certain woman from inland, from Paorani, the place where Tematauira lived. And this woman came with a gourd for seawater, and this woman saw that person, Haatauhi, fast asleep on the beach. The woman returned inland to Paorani, and told Tematauira and his people of the person she had seen, asleep on the beach in the midst of the *pohue* bushes, with his *parani* close beside him. The name of his *parani* was Orooromauna. This person was brought, and thus they knew here indeed was Haatauhi, arrived here in Tubuai. Tematauira was greatly pleased, and they two dwelt together in the place.

One day the battle commenced between Tematauira and Haatauhi on their side, and the nation, Temarere on their side. They fought in Taahuaia. The sort of fighting was cutting with *parani,* and in this great and terrible battle was exterminated the nation, Temarere.

Then Tematauira told his people to go and see what was the nature of the killing of the people: "Those cut deeply, cut as with bamboo, were cut by me with my *parani,* by Paorani. But those smashed, that is, those crushed, were [killed] by Haatauhi with his *parani,* with Orooromauna." Then the people went and inspected the marks, and it was seen that those cut were cut by Haatauhi, but those crushed, were crushed by Tematauira. This is the way it was known whether they were cut by Tematauira or by Haatauhi. They saw that all the people cut deeply had the cut upon the left side, and they knew it was done by Haatauhi, because Haatauhi was left-handed. But the people whose bodies were crushed were not cut on the right side in the place crushed, thus they knew these to have been [killed] by Tematauira, because Tematauira was right-handed. Thus is was known to the people that Tematauira had lied; he was angry and decided to kill Haatauhi, because he and his *parani* Orooromauna were praised by his people.

One day Tematauira said to Haatauhi, that they should go up on the mountain and throw stones, to see which of the two of them was stronger, and whose stone would fly the farther. They went up to the top of Mount Panee, and Tematauira threw his stone up on Mount Hanareho, but it did not get there [to the top], because of the distance; the distance is about 4,000 fathoms. Then Haatauhi took his stone, and threw likewise up on Mount Hanareho. His stone went right to the top of that mountain, Hanareho. Very angry indeed was Tematauira, and decided that he should kill Haatauhi.

And then, at that time, Haatauhi rose in the air to fly to his land, Borabora,

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because his work was finished, but he was stabbed by Tematauira with a spear, and thus Haatauhi died. It is finished.

PIPINI-MA

Araiatehere of Rurutu gave the following chant:

Haere ra aia e rama noara ta raua i'a;	They have gone by torchlight for their fish;
Haere ra aia raua i te fare;	They have returned to the house;
Tunu ra aia ta raua i'a;	They have cooked the fish;
E ama, tamaara aia;	When (the fish were) cooked, they dined;
E paia, haapae ra aia i te ivi na Pipini-ma;	Satisfied, they set aside the bones for Pipini-ma.
Haere ra aia Pipini-ma i vaho e haere ra aia i nua i te tahuhu;	Pipini-ma went outside, and went upon the ridgepole.
Tuo ra aia te na metua ia Pipini-ma:	The parents called to Pipini-ma! (chant)
Pipini-ma e, ho'i mai!	"Pipini-ma, come back here!"
Tuo ra mai Pipini-ma i te na metua:	Pipini-ma called back to the parents,
Eita maua ho'i atu!	"We shall not return there!"
Pipini-ma, ho'i mai!	"Pipini-ma, come back here!"
Eita maua ho'i atu!	"We shall not return there!"
Tautai ino te ramarama!	The torchlight fishing wrought evil to the offended, orphaned children,
Tautai faatii tamarii e, no Tare!	Orphaned, orphaned,
No tare, no tare.	They have already been changed, they have already been changed,
Hariro a'enei, hariro a'enei, Na pupa-ura i te ra'i e.	Into twin flower-clusters red-gleaming in the sky.

For the final line in this version as related by Araiatehere, I have substituted the final line of the version recorded by Mr. J. Frank Stimson, in Tahiti. As told by Araiatehere, the story is at the last confused with something quite irrelevant, and the final line in particular is at variance with all other versions heard. The translation of the thirteenth and fourteenth lines may be inaccurate, but expresses the idea at least. The Tahitian word for orphan is commonly *otare;* the word given by my informant was quite definitely *notare,* or *no tare*. I could not find any meaning for such a word or expression, unless *tare* might have referred to one of the parents; this was denied, the parents, names as given by my informant but disputed by others, were To(h)ora, the father, and (H)onu, the mother. It seemed quite possible that *otare* had for some unknown reason, by accident, become *notare,* and I have translated accordingly.

PIPIRI-MA, A VARIANT

Mr. J. Frank Stimson in Tahiti recorded the following:

"Pipiri-ma e!	"O, little brothers! Come back to us!"
Ho'i mai e!"	"Ne'er shall we return to you!"

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"Eita maua e ho'i atu!"	Ill bode the night fishing by torch-light
Tautai ino te ramarama,	To the little children neglected;
Tautai faatii tamarii e	Ere now they have been changed into twin flower clusters.
Ua riro a'enei na pupa-ura i te ra'i e!	Red-gleaming in the sky!

TAIE

The story of Taie was told by Suzanne Terihiane of Rurutu:

There were born to a woman in Rurutu three sons. Two of the boys went to the war; the mother and the other little son remained at home. Later on the mother learned that her two sons had died in the war. The boy decided to go to the war, but his mother would not give her consent. One night the boy thought to hide from his mother. When daylight came, the boy ran down to the sea shore, and made a ship. The boy was named Pehora; his younger brother's name was Taie. The boy went aboard his ship, and the ship sailed out to sea; Taie heard the sound of battle out upon the ocean. His ship pursued the British fleet; the British fleet met the fleet of the *firitete* (the fleet of frigates?) at sea, out on the ocean. They battled: the ships of the *firitete* perished, the ship of Taie survived. Taie's ship went to the shore.

There came another year, and Taie met a certain girl; Taie wanted to embrace her, this daughter of the chief. Taie went in pursuit of that girl, but did not obtain her, because a person would be killed if he took that woman. One day he went into the house of the chief to get that girl. He ascended to the floor of the house, and went inside. That woman was asleep there. He took a rose, and tossed it upon that woman. That girl came out and met Taie, they kissed each other, there outside. They went down to their ship.

The ship departed, and sailed far out to sea; the sailors were greatly troubled. The sailors decided they should kill Taie. The ship approached land, and the sailors were greatly angered at Taie. Taie was thrown over into the ocean; the sailors were left on the ship and also the woman.

Their ship made port; they went ashore to the mother of Taie. The sailors lied to the mother of Taie. The father was dead, the mother still lived. The mother thought Taie had returned, and sought her son, but he was not to be found, because Taie had not come ashore, he was dead in the sea out on the ocean. The mother died at that time. It is finished.

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RELIGION

Nothing remains in Tubuai to indicate what may have been the religion of the days previous to the arrival of the Christian missionaries except the ruins of old maraes, many of which have so completely vanished that not a stone remains to mark their sites. Little can be learned of the history and use of the few that are preserved. (See p. 118.)

The conversion of the people to Christianity has been so complete that even the oldest inhabitants appear unable to recall any knowledge of the religion of their forefathers. It may be that if such knowledge exists, it is carefully concealed. The only reference to dieties of ancient Tubuai was in connection with the genealogical tables of two families, both of which were traced more or less directly from ancient gods. Tautu a Mauritera, a Tubuai man from whom I procured many hints about ancient customs, said that in days gone by it was customary to offer prayer before starting out fishing; in modern times, before drawing the net known as the *rau ere*, prayer is offered for success. It seems possible that this prayer to the Christian God may be a survival of the older form of prayer to the primitive god. Similarly a native schooner never leaves port without prayer service; formerly gods were taken on voyages.

A Tubuai man, Teata, while disclaiming knowledge of any ancient religion on his own island, readily gave me the following information on the ancient religion of Rurutu—a story which has been neither verified nor discredited, except that the names of the three gods were also recorded by Stokes (43) in Rurutu.

Taio Aia was the supreme god. Lesser, presumably local gods, were Terii Rerehiti and Rua Paauri. The marae of the supreme god was named Tooura, and was near the modern village of Avera. Sacrifices, generally human, were offered to him there; if they were not offered regularly, he became angry and seized (*rave*) children. Adjacent to his marae was the umu in which the sacrificial victim was cooked. The body was placed in sitting posture; when it had been in the umu for several hours, the priest uncovered the head and pulled out a few hairs. If they came out readily, the body was considered sufficiently cooked. The priest took the cooked head to the marae and offered a prayer to the god. He then ate the outer flesh from the head, and gave the inner parts to the god. The informant was not certain what disposition was made of the remainder of the body, but thought it was eaten by the people assembled at the marae.

The religion of the present day Tubuai people is for the most part a development of teachings of the London Missionary Society, under whose influence the people have lived since early in the nineteenth century. Native teachers who had received instruction in Tahiti or Moorea were sent as

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missionaries to Raivavae in 1820, and again in 1821. Rurutu received the gospel in an accidental manner. In 1821 a canoe from Rurutu drifted to Raiatea, touching at Maupiti en route, and the Rurutu people on board were converted by the missionaries at Raiatea. Returning to Rurutu, they were easily able to persuade most of their countrymen to adopt the new religion. Word of the new religion was soon afterward received in Tubuai. In 1822 the chief or king sent to Tahiti for teachers. In 1826 the profession of Christianity was general in Tubuai. What disposition was made of the images of the ancient gods is not known certainly. From Rurutu a number were taken to Raiatea and turned over to the missionaries there; some, at least, were destroyed by fire. In Raivavae, some of the stone idols (*ti'i*) still exist, and others can probably be brought to light, as informants say that many were buried at the time of the adoption of Christianity. There is no record that any Tubuaian idols were turned over to the missionaries, but none is to be found at the present time. Search was made in the neighborhood of all maraes visited, without success. One old man said that his father had unearthed a stone image, but had immediately buried it again. He tried to find the place of its interment, but after a few days of half-hearted search, gave up with the final comment, "It has probably been destroyed by God long before now, anyhow."

The churches of the London Missionary Society hold the dominant position in Tubuai. The Church of Jesus Christ of Latter Day Saints, enrolls about one-quarter of the population and the Reorganized Church of Jesus Christ of Latter Day Saints has a considerable following. There are also a few Roman Catholic followers of the resident French priest.

The early missionary records were searched for information relative to the ancient religion of Tubuai. Upon inquiry the Secretary of the London Missionary Society stated that the early records are at present difficult of access, but that the Society hopes to make them available in the not distant future. Similar reply was made by Elder Joseph F. Smith, Historian of the Church of Jesus Christ of Latter Day Saints, who kindly sent extracts relative to the establishment of the first mission of his church in the Pacific, in Tubuai, 1844. No mention was made, however, of the former religion of the Tubuai people.

DEATH AND BURIAL CUSTOMS

Death, when due to natural causes, is not dreaded by Tubuai people to any unusual extent. Death caused by accident, particularly when the victim is alone at the time of his death, is regarded as frightful (*riaria*). Death at sea, and death by drowning, are especially frightful. An old man in Taahuaia was known to be near death; his relatives and friends were quite cheerful and did not greatly mourn his final departure, as death came naturally and

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when he was surrounded by friends. A Tubuai man was killed accidentally in another island; he was alone at the time; his relatives and friends were very deeply affected. A near neighbor of mine in Mataura failed to return from a fishing trip, and was finally given up as lost at sea; his relatives, friends, and all who heard of the affair were overcome with horror at the thought of his having perished at sea, alone.

In response to inquiries concerning former burial customs, some informants said that a body would be preserved by drying, being anointed from time to time with *monoi* and kept wrapped in mats in the family residence, or in a house built especially for the body. Others said that a body was preserved only a few days in this manner, and was then buried conveniently near the residence of the bereaved family. The grave was covered with a low mound, outlined by a row of stones set on edge. The mound was covered with white tapa, upon which various objects were placed in honor of the deceased. Opinions differed as to the nature of these objects, but the general idea was that they were offerings of food or implements for the use of the spirit in its travels to the next world.

This spirit world was by some called "Havaii-i-te-Po," by others, "te Po," and by others was identified with the missionary teachings of Heaven.

Mourning customs included the scarification of the head with sharks' teeth or knives, and the cutting of their hair by women. Such customs, though described by several people as having existed only fifty years ago, are not observed in modern Tubuai.

Modern burial customs differ little from those in any country where embalming is not practised. The body is bathed and dressed in the best possible garments, and interred within 24 hours after death. Relatives assemble for the services, but except for those most closely related there is little display of grief. After the funeral the gathering has rather the aspect of a family reunion.

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ARCHAEOLOGICAL SURVEY

KINDS OF RUINS

The archaeological remains in Tubuai include maraes, village and home sites, burial places, either isolated or in groups, curbed wells, curbed and paved bathing places, stone walls marking land boundaries, paved roadways and stepping stones across streams and low ground. The more important of these features have been plotted on the map (Pl. I). The natives of Tubuai do not object to any sort of archaeological work, but government regulations proved a serious obstacle. Many of the sites visited could not be studied, and it did not seem worth while to spend time and money on clearing land where excavation could not be done.

MARAES

Structure

The maraes in Tubuai seem to have been relatively simple structures. The type is a rectangular space bounded on three sides by a fence of stones set upright in rows like pickets. (See fig. 5.) The size of these varies considerably in the different maraes: some are huge slabs 7 or 8 feet long with cross sections in proportion; others are hardly more than cobble stones. The largest seen stood 10 feet high above ground and measured about 2 feet by 4 feet. Seale (39) mentions a marae on the north side of the island

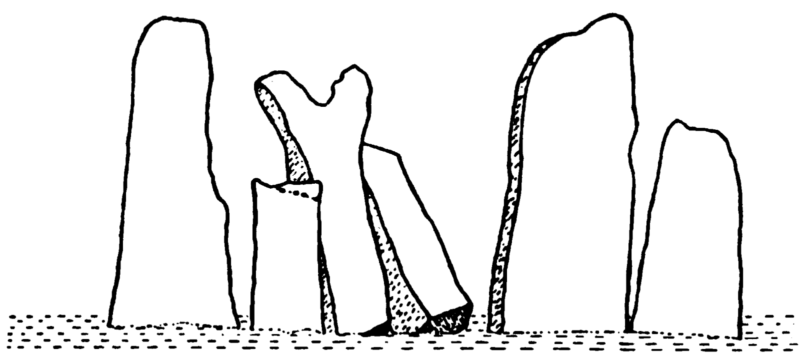

Figure 5.—Sketch of stones forming part of the fence of Marae Tamatoa.

in which the stones are exceptionally large. His figures for the largest three are: 10 feet high, 6 feet wide, 1 foot thick; 9 feet high, 9 feet wide, 3 feet thick; 9.5 feet high, 7 feet wide, 1 foot thick.

I did not locate a marae with stones of these dimensions but one on the north side of the island has many stones above the average in height and width. It is possible that this is the marae mentioned by Seale and that the largest stones have been broken or dragged away to build bridge abutments on the nearby road, a fate that has befallen many stones from maraes. Or it

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may be that in his pursuit of birds, Seale made his way through the seemingly impenetrable undergrowth to places not visited by me.

The amount of labor involved in the transportation of the stones to their final resting places in the maraes must have been enormous. Few of the large stones weigh less than 1/2 ton and the largest one measured weighs about 4 tons. The 10-foot stone mentioned by Seale has a displacement of at least 50 cubic feet (allowance being made for the irregularity of its form and for the amount below ground level) and weighs probably 4 tons. Even the average large stone weighs 1/2 ton or more. Furthermore, many of the maraes are at a considerable distance from places where such stones might have been obtained and some are at elevations above any possible source of supply.

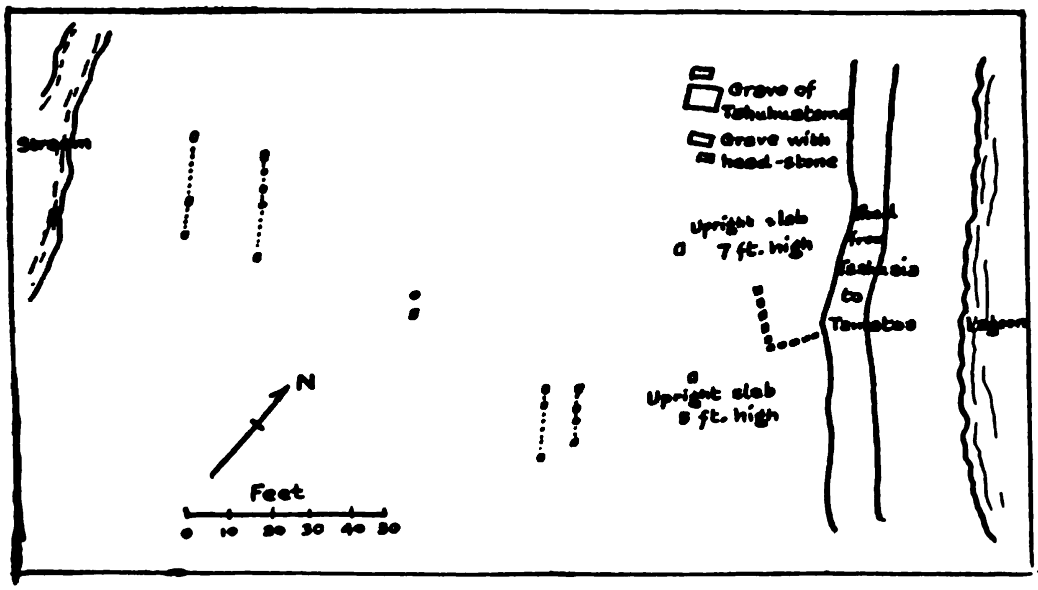

FIGURE 6.—Sketch of ground plan of Marae Peetau.

None of the stones shows evidence of having been cut to shape or size, except the few slabs of coral, some of which have been roughly shaped.

Several of the spaces enclosed within the fence are roughly paved with irregularly disposed stones either small slabs or rough stones with a flat face uppermost. These slabs or stones vary. In several of the best preserved maraes the pavement is practically complete; in others it is partially or entirely lacking. It seems probable that originally all were paved, and that those now lacking pavement have had it removed. From one marae at Huahine, all the small stones from the fence and pavement were removed for use in building. Another was robbed of most of its small stones and some of the larger slabs to repair a road. A third, near the beach, has furnished hundreds of stones for canoe anchors.

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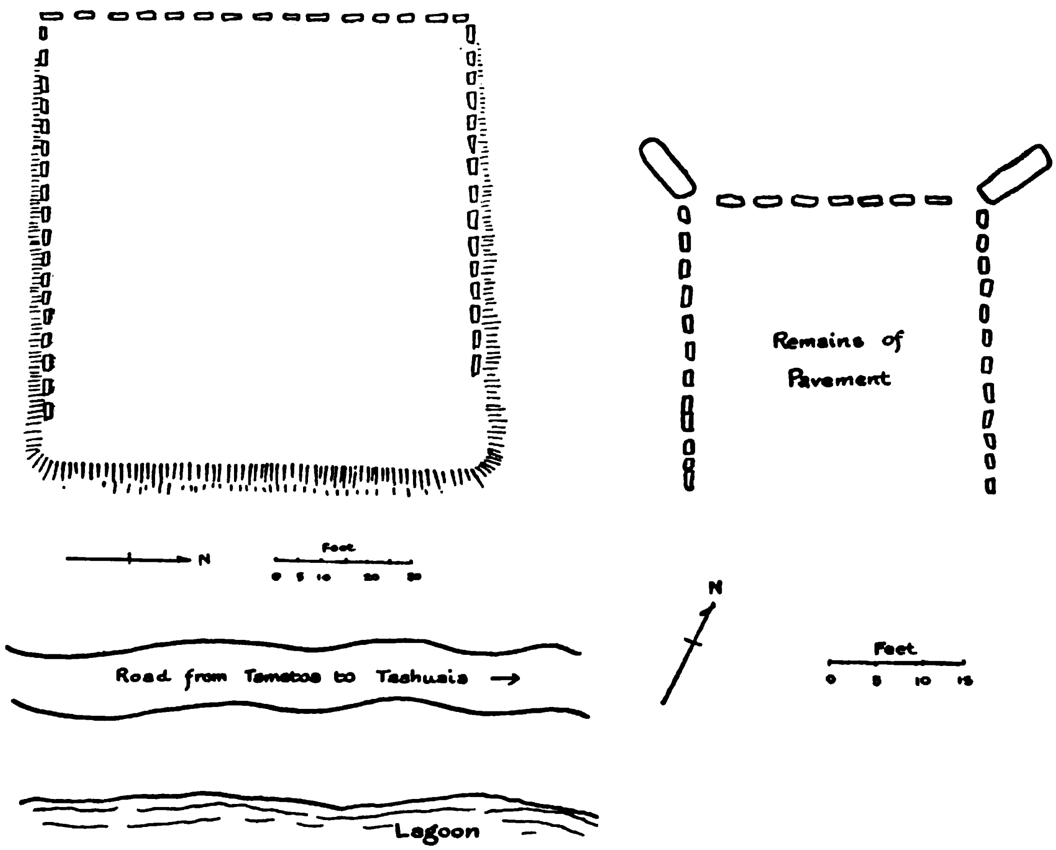
In size the maraes vary greatly. The largest, that at Tehaunatieva, with its subordinate structures covers about 2 acres (p. 127) and the broken pavement about 1,000 square yards. It may be that the marae Peetau was even larger (fig. 6). The smallest marae, that at Huahine, is little more than 30 feet on a side, although scattered stones in the immediate neighborhood suggest that at one time other enclosures or pavements may have formed part of this marae. The two side fence lines are longer than the end line, except in one marae, where it is not unlikely that stones have been removed



a *b*

Figure 7.—Tubuaian marae: *a*, ground plan of marae at Potuitui; *b*, ground plan of Marae Tamaruaorai. (Sketched from field notes and measurements, stones represented conventionally.)

from the ends of the side fences. The side line fences are parallel forming right angles with the end line. There is no evidence that the maraes were oriented, the direction of the fence lines being in general determined by the slope.

Nearly all maraes were either placed on level land, or if on a hillside, followed the slope of their site. Except at Potuitui (fig. 7, *a*) there is no indication of levelling or filling.

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Two similar terraces were observed, each now the site of a modern house. At each place there are remains of pavement, but no fences, but portions of the pavement are slabs of a size that suggest portions of an original fence.

Marae Tamatoa

Marae Tamatoa in this district of the same name lies about one-quarter of a mile from the beach, 100 yards above the base of a mountain ridge. It is regarded as one of the principal maraes of the old days, and is in an excellent condition of preservation. At the time of my visit there were objections to clearing the site, consequently only such photographs were taken and measurements made as could be done without too greatly worrying the proprietor. I believe the site to be of importance, and that adjacent ruins are associated with it.

Seale in 1902 visited this marae and removed from it a portion of one of the stones, bearing curious markings (45). This stone fragment is now in the Bernice P. Bishop Museum. I found without difficulty the remainder of the stone, and examined it and all the other stones in the marae without finding traces of similar markings.

In form and size Marae Tamatoa is typical of the Tubuai marae.

It is rectangular, fenced in on three sides by upright stone slabs arranged in practically straight lines meeting at right angles, and is completely paved with smaller stones laid irregularly, but uniformly with the smoothest or most nearly flat side uppermost. The longer sides are an even 100 feet in length, the end slightly over 30 feet long. There is indication that at least part of the space immediately adjacent to the fences on the outside of the marae, is paved or marked off by curbing. The extent of this pavement or curbing could not be ascertained without further clearing the dense undergrowth. At various places in the immediate vicinity of the marae, stones distributed in the tangled brush suggest paved areas and imperfect rows, indicating an extensive structure or series of structures.

One striking feature of Marae Tamatoa is the average great size of the stones forming its fences. Many exceed 6 feet in height, and an estimate of weight would place the average at over a ton. (See fig. 5.) The largest stone in the marae stands more than 9 feet in height above ground, and I estimated its weight as more than 3 tons.

On the side of the marae toward the mountain, about 2 feet within the line of the fence and midway of its length, stands a small slab suggestive of a grave headstone. I could learn nothing of its purpose. There are no other indications of burial within the marae, the stones of the pavement seemed not to have been disturbed, and there is no mark of any kind on the stone. It seems more likely that the stone served to mark the position of some person taking part in the ceremonies of the marae, or perhaps, as suggested to me by Stokes, to mark the corner of a house or structure of some sort within the marae. No other stones were found in this or other maraes that at all resembled this one in appearance or position.

Marae Tamatoa is one of several belonging to the former ruling family of Tubuai. The name seems to be a very old one in Tubuai and in the Society Islands. In 1844, the island was governed by Tamatoa, one of sev-

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eral Tubuai kings by that name who reigned successively until the French took possession. From Tubuai genealogies it cannot be determined when Marae Tamatoa was built, who first took his name from it, or gave his name to it, or who the patron deity was. No tradition is now connected with it.

Marae Peetau

Few stones remain to mark Marae Peetau (fig. 6), originally one of the greatest maraes in Tubuai. A nearby road has doubtless been repaired many times with stones taken from its fences and pavements. At least one enclosure lacks an entire fence, and the stones may now be found in the abutments at a nearby bridge. The marae has also supplied stones for building foundations in Taahuaia.

Marae Peetau also belongs to the Tamatoa family and the present day descendants of Tahuhuatama, the last of the royal line to reign, are the recognized owners of the site. Tahuhuatama, or Tamatoa IV, was buried at this marae, his grave being marked by a prostrate half cylinder of solid masonry measuring 10 by 15 feet, with a radius of more than 5 feet. Nearby are graves of members of his family, marked as are the modern Tubuai graves, enclosed in rows of small stone slabs set on edge. One of these graves has a larger slab rudely cut in headstone shape, inscribed in chiseled letters now almost illegible. The inscription, as nearly as it can be deciphered, is as follows:

EARAI
RE·IPOHE
MII RAO
MD·58

No one now remembers whom the stone commemorates; *i pohe* means died, but the rest of the inscription was meaningless to the various Tubuai people who attempted to help me decipher it. All that can be said is that the grave must be that of someone who died at least two generations ago, but not more than a hundred years ago, as before that time there was no knowledge of writing.

The land occupied by Marae Peetau has been farmed repeatedly, no respect having been paid to any part of it except the actual graves. The stones marking these have not been disturbed. The graves nearest that of Tahunuatama are enclosed by a closely set hedge of panex, standing 15 feet high.

Parts of the site are densely overgrown and parts are cultivated. The larger stones remain, but many small stones have been carried away for building pavements and fences. The entire area is littered with stones, but

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only a very few may be assumed to occupy the positions they did when the structures of the marae were complete.

It is possible that were the entire site to be cleared and the exact position of every stone charted, an idea could be gained of the original marae. The sketch (fig. 6) represents all that could be recorded without clearing.

A legend states that Marae Peetau was in existence while Paorani, one of the ancient settlements of which there are no remains, was the seat of the chief of the district. But no reference is made in the tale to any ceremonies or deities of the marae, and no verbal information could be obtained. That it still retains some of its old-time importance is indicated by the presence of graves of members of the Tahuhuatama family, but its doom can be read in the intention of the present generation to completely clear the site, except for the graves, and plant the land to coconuts.

Marae Tonohae

Of Marae Tonohae (Tonoha'e) there is at present almost nothing left to indicate the character or extent of the original structures. Like Marae Tamatoa and Marae Peetau, it belonged to the family of Tamatoa, and was regarded as of great importance in ancient times. Present day descendants of Tamatoa still speak of this as one of their maraes, and its name is preserved in the sur-names of several living persons.

Marae Tonohae is supposed to have been built by Hilo, or Hiro, as his name is generally pronounced in Tubuai. A few people have Maui confused with Hilo, and state that this marae was built by him, but Hilo is the more generally accepted. Hilo is said to have come from Havaii-i-te-Po to Raivavae, where he built Marae Temahara. Bringing with him a stone from that marae, he came to Tubuai, where he resided for some little time, and built Marae Tonohae, using the stone from Marae Temahara in its construction. Then he journeyed to Rurutu, where he built Marae Ahotea, using in its construction a stone from Tonohae, and from Rurutu to Rimatara, where he built Marae Tonohae, using a stone from Marae Ahotea in its construction. These other maraes, at the islands mentioned, are all in existence, but all are now more or less in ruins. Accounts from Raivavae and Rurutu check the Tubuai accounts of the building of the marae by Hilo, and of a vague association among the maraes because of the use of stones from one in the construction of another.

The description of Marae Tonohae can be only vague. Old people told me that in their childhood, fifty or more years ago, there still existed patches of pavement and fragmentary fence lines, but that the habit of using these stones as canoe anchors had reduced even these scattered remains. The few stones still in place indicate that the structure or structures occupied consid-

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erable land, probably not less than the site of Marae Peetau. Some of the stones are quite as large as those seen at Peetau or Tamatoa. It seems probable from all accounts that Marae Tonohae was originally an extensive structure or series of structures, with side fences and pavements like those of other maraes, but that its situation so near the beach at a center of population rendered it peculiarly liable to destruction. An additional factor in its destruction is that the first Christian missionaries whose work of destruction was so thorough, make their headquarters in the neighborhood of this marae.

At the present time there remains one remarkable part of the marae: a depression, rectangular in shape, about 6 feet wide and 10 feet long, found only a few feet from the largest stones still on the site. This is said to have been the umu associated with the marae, and some say, while others hotly deny, that the purpose of the umu was the roasting of the victims of battle or treachery, whose bodies were afterwards taken to the nearby maraes and eaten. One other such depression was found still littered with old umu stones at the roots of the grass and undergrowth. There are no maraes in its immediate neighborhood, but there is no need to assume that in former times there may not have been, as the land has been cultivated for generations.

Marae at Potuitui

The marae at Potuitui is situated only 50 yards from the beach on a site now used as a door-yard (fig. 7, *a*). The modern Tubuai people cannot or will not recall its name. Its fences are still in fair condition; but the pavement, if any existed, has been removed.

A distinct feature of this marae is the terrace of which its fences are the boundries. The ground has been filled in, without, however, any indication of cutting at the upper end. It is evident that the stones were set in place after the terrace was completed, the slope of the sides of the terrace being just outside the lines of the side fences. The end of the marae toward the sea is open: the terrace here continues about 20 feet beyond the ends of the side wall, but terminates in an abrupt slope parallel to the inland end of the marae. It seems probable that formerly the side fences continued to the seaward end of the terrace, as all the other maraes seen in Tubuai had sides longer than the ends, and there are stones now serving as pavement in front of the house within the marae that in every way resemble those remaining in the fences.

Marae Tamaruaorai

In the interior of the island, near the present road from Mataura to Mahu, there were formerly many maraes. Most of them have been completely destroyed, or so nearly so that not enough now remains of their fences and pavements to indicate their former appearance, or, indeed, for some of them, their exact locations. One of the best preserved is the Marae Tamaruaorai (Tamaruaora'i) at Huahine (fig. 7, *b*).

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Three sides of this marae are still nearly intact, although many of the small stones of the fences and nearly all of the former pavement have been removed. The meeting house of the Church of Jesus Christ of Latter Day Saints, a short distance from the marae, has incorporated in its floor and foundations most of these stones! The larger stones of the fences still remain, many upright, some fallen, showing clearly the former lines of the enclosure. There is no evidence of a fourth fence. In the neighborhood of this enclosure there are a number of stones, some still indicating former fences or pavements, but so scattered and so hidden by undergrowth that extensive clearing would be necessary before the site could be accurately mapped.

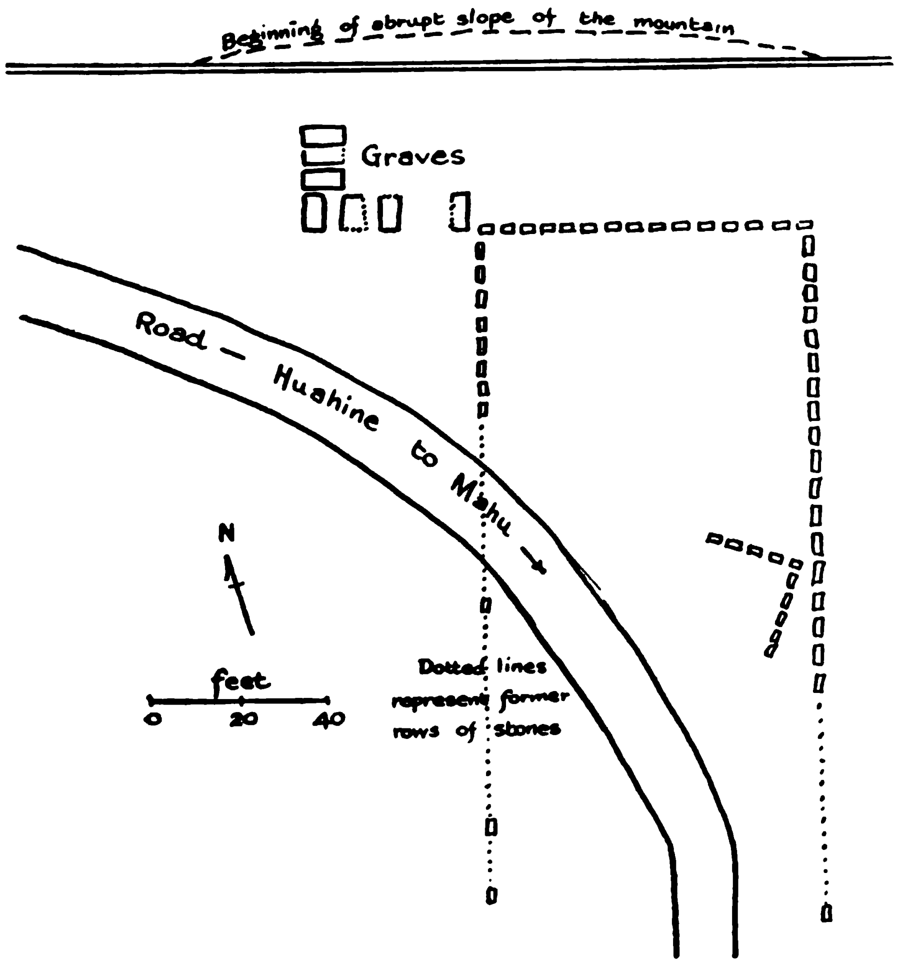

FIGURE 8.—Ground plan of Marae Tahiriura at Mahu sketched from field notes and measurements.

That excavation of this site is desirable is suggested by the frequent discovery of stone adzes or fragments of similar stone implements by those engaged in cultivating land in the neighborhood.

MARAE TAHIRIURA

A second marae in the interior of the island, not far from Mahu, and cut by the road from Huahine, is Marae Tahiriura (fig. 8).

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The portions of the fences that still exist are exceptionally well preserved. Almost all the stones of the side fences from the points of intersection with the road to their ends at the open side of the marae have been used in regrading the road, and the smaller stones of the pavement, of which there is now not a trace, are said to have met the same fate. The undisturbed stones of the fences, together with the five stones remaining in the sections demolished by the road makers, indicate the enclosure to have been one of the largest seen in Tubuai. Within the principal enclosure are two sections of fence, meeting at a right-angle corner, the direction of these fences being at variance with those of the marae proper.

On a prolongation of the end line of the marae is a row of graves, said by present-day people to be graves of the *etene*, or heathen, and to have been there for many generations. This row extends in single rank for 37 feet, there forming a right angle with a similar row extending northward for 22 feet. All the graves are similarly marked, by enclosing rows of small stone slabs set on edge. Many of the slabs are missing; it is entirely probable that there may be other graves not now marked.

It was not practicable to photograph this marae or any part of it. The entire site is covered by a very heavy growth of coffee trees and the owner naturally objected to any clearing.

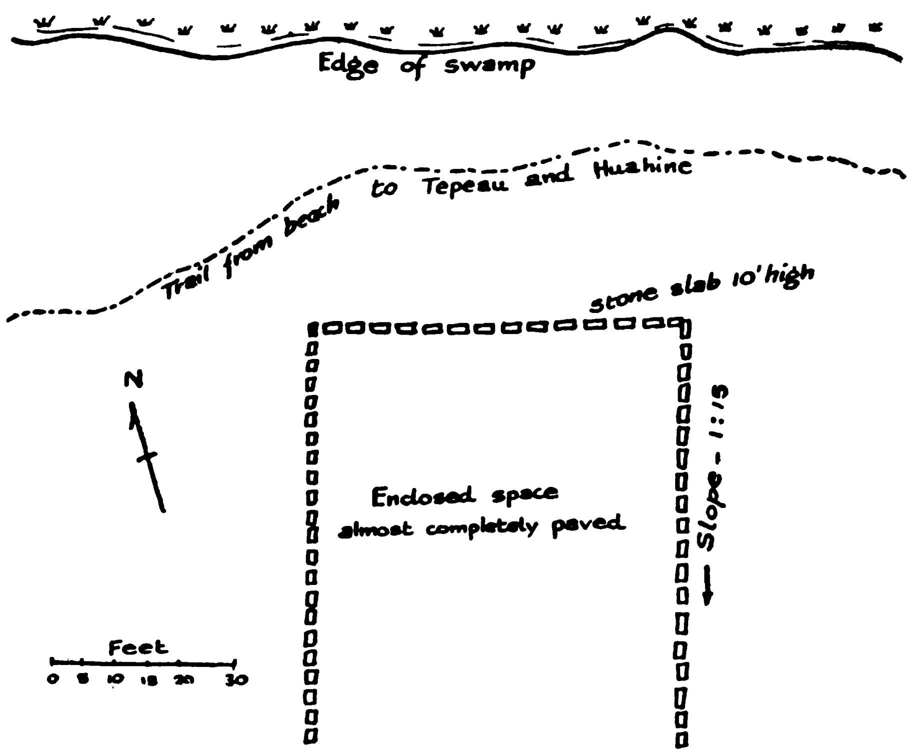

FIGURE 9.—Ground plan of marae at Tanitepu sketched from field notes and measurements, stones represented conventionally.

MARAE AT TANITEPU

Like most of the maraes in Tubuai, the one at Tanitepu (fig. 9, *b*) has been forgotten so completely that it has no recognized name and the few people who know of its existence pay little or no attention to it. Lying at a

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considerable distance from any of the modern villages and main roads, it has not been greatly disturbed. The entire site is covered with dense undergrowth, except for part that bears a heavy stand of coffee.

The land section Tanitepu, within which the marae lies, comprises a few acres lying between the steep slopes of the mountain and the border of the swamp. In former times this strip is said to have supported a large population tributary to the ancient village of Tuporo, a statement that is borne out by the presence of terraces of taro patches, long unused, of numerous maraes in varying stages of ruin, and of house sites and land boundary walls of stones heaped in rough rows.

The marae at Tanitepu is of typical form of Tubuai. It is rectangular, marked off from the adjacent land by fences of upright stone slabs along two sides and one end, the other end open; the enclosed space is paved with smaller flat stones and slabs. It is almost exactly oriented, but I believe this to be incidental, as the slope of the land is such that any other placing of the marae would have been almost impossible. Many of the stones in the fences are very large; one near the northeast corner stands 10 feet above ground and has a cross section 1 1/2 feet by nearly 4 feet, at its base. The size of the stones is not surprising, as a source is close at hand.

No graves and no other rows of stones or remains of pavement were found in the neighborhood of this marae. A few stones, not arranged in any particular order, but seemingly not naturally disposed, lie directly below the marae at the very edge of the swamp. It was suggested by a native that they may have been associated with an ancient bathing pool, or waterhole. A few stones lie along a strip of elevated land which extends out into the swamp from a point near the marae, suggestive of the stepping stones laid in swampy places along the old trails. The fill, if such it is, now ends 50 yards from the edge of the dry land, and seems to lead nowhere. Investigation failed to show any similar fill extending from the dry land at the opposite side of the swamp, such as might be expected if there had been a pathway across the low land.

Marae at Tehaunatieva

The marae at Tehaunatieva (Te hau nati'eva) is in a very poor state of preservation. The number of stones scattered about is enormous, but their arrangement is obviously due to chance, and except in a few places where an occasional stone stands erect, no idea can be gained of their original positions.

Along the sides of the area there are remains of fences, and at the upper end of the site, which is on land sloping about 15 feet in 100 feet, stands a section of fence about 30 feet long. The side fences are indicated merely by occasional stones of small size, quite different from the large slabs of other maraes. They seem to have originally marked off an area about 60 feet wide and at least 150 feet long. The stones scattered within this area are similar to those found in pavements of other maraes, and probably served as such before the land was farmed. Some 50 feet down the slope from the lower end of the area now littered with loose stones stands a solitary large slab, 7 feet in height.

Near the upper end of the enclosed space, within the lines of fence, are two areas which appear to be graves. They are marked off from the adjacent land by rows of stone slabs, just as are the graves at Marae Tahiriura, but differing in that the slabs used here are of coral. A second difference is that the spaces within the enclosing

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rows of stones are heaped with gravel and small fragments of stone, and that they are considerably longer than those at Marae Tahiriura. They resemble closely graves found at the site of the ancient village Tuporo, and at the marae on the north slope of Mount Hanareho.

It may be significant to note that these graves, if such they be, are similar in appearance to platforms within the crater of Haleakala, Maui, as described by Emory (21).

Marae on Mount Hanareho

In his notes on Tubuai, Seale (39) mentions a marae "of immense big stones . . . on the mountain at an elevation of 1,000 feet." Careful searching failed to reveal this marae, until an accidental fire, only the day before my departure from Tubuai, cleared the dense grose on one of the lower northern slopes of Mount Hanareho. This revealed a marae which I believe may be the one seen by Seale, although its altitude above sea level is considerably less than estimated by him. I was able to give only a few minutes to the examination of this marae, and obtained only a very indifferent photograph of it.

The marae is of the usual type, enclosed on three sides only with fences of upright slabs, and the enclosed space covered with fragments of stone scattered to form a very rude pavement. At present, the small pavement stones are strewn about in a manner which suggests that the fragments now resting quite on the surface were formerly imbedded in the soil, and brought to their present position by the washing away of the loose top soil.

From my hasty notes at the time, without careful measurements, I should describe the marae as being about 30 feet wide, and at least 50 feet long. The stones in the fences are not exceptionally large, but are practically all in place. On the slope above the marae, and 30 or 40 feet to the west, is a platform similar to those at Tehaunatieva, assumed by me to be graves. A quarter mile to the east, and a few yards higher on the slope are a few stones arranged in two rows meeting at right angles. These may be the remains of another marae similar to the one described, as other stones are scattered all over the adjacent land.

This marae is in a very lonely spot near a trail little travelled, and the land upon which it stands appears never to have been cultivated. I was unable to find anyone who knew its name, or, in fact, anyone who knew of its existence.

Marae Vaitauarii

Marae Vaitauarii lies on cleared land a few hundred yards from the beach at Tepuu, between a swamp and the base of Mount Mareiura. The ancient water hole and bathing place, near at hand, are a favorite resort of the women folk of the neighborhood, who use the stones of the marae to dry the clothes they wash at the water hole.

The name Vaitauarii was given me by an informant whose previous information always proved correct; another informant gave the name Tetai-

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rama, which the first informant applied to another site at some little distance. The photographs taken of this marae were unfortunately ruined and the field book containing measurements has been missing since one of my trunks was rifled at Papeete. The following description is perforce from memory.

The marae is situated on a level bit of land only a trifle larger than the marae itself. In form, it is similar to most maraes in Tubuai, with the exception that the pavement consists of larger blocks of stone. The enclosed paved space is about 30 feet by 45 feet, and the sides are not oriented. The stones in the fences average about 3 1/2 feet in height.

The water hole is roughly circular with a diameter of about 5 feet, and is about 4 feet in depth. The sides are walled to the level of the surrounding ground with stones from the size of a brick to four or five times that size. The water hole is really a spring, and the flow is led through a covered gutter of closely laid stones to the bathing place, 12 to 15 feet farther down the slope. The bathing place is a rectangular pool about 8 feet wide and 15 feet long. Its sides are walled like those of the water hole, their greatest height above the bottom of the pool being about 4 1/2 feet. The bottom of the pool is paved with large slabs, now covered by several inches of silt. The overflow from the bathing place is led through a spillway down to the taro patches at the edge of the swamp..

Some people claim that the site is that of an ancient dwelling, rather than of a marae, and that the name, Vaitauarii, is that of the spring and pool. But the more generally accepted idea is that there was a marae at the place, and that the owner of the land dwelt as does the present owner, in a house down near the beach. It is said that many stone adzes, chisels, and pounders have been cast into the water here. If so, they are effectually hidden in the silt, for I failed to find even one.

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STONE IMPLEMENTS

By John F. G. Stokes

(Illustrations by Y. Kenjo and Verna Tallman.)

Stone artifacts collected from Tubuai include adzes, pounders, sling-stones, coral graters, and smoothing stones for mat-making. Waterworn pebbles said to have been used as sling-stones resemble countless hundreds of other pebbles. The coral coconut greaters common in Tubuai households, are pieces of ordinary coral said to have come from a reef near Mataura. Aitken states that the smoothing-stones are in daily use. Some were given to him by a mat maker who remarked, "Anyone can find plenty of others as good or better in the nearby stream, from which I took these."

ADZES

Source and Material

Of the 96 Tubuai adzes in Bernice P. Bishop Museum, 85 show the characteristics of the completed implement. This number includes one adz localized as from Raiatea and three as from the Marquesas, which however are unlike the adzes from these islands but which correspond closely with the Tubuai forms. It is of interest to note that all four are hafted with the blade inverted—a modern error perpetuated by Caillot (13, pl. 75). Tubuai adzes are well represented in European and American museums and there are many in Tahiti.

The locality within Tubuai is known for none of the specimens. Aitken observes that the adzes were brought to him by natives who had no idea of the original source, and that any attempt to correlate the adzes with clans or localities was futile. Some of the adzes had been stowed away in chests, perhaps as family heirlooms, but more likely because of their potential value as curios. Foreigners have lived on Tubuai for many years, and visitors are not uncommon.

Among the Tubuai adzes are a few which unquestionably were made elsewhere. One is a recent importation from Rapa; others, referable to Samoa, Tonga, Rimatara or Cook Islands, and the Society Islands (p. 156) may have been imported while stone adzes were still in use. Despite these importations the number remaining is sufficient to identify certain forms as unquestionably of Tubuai origin, an identity verified by many incomplete but characteristic specimens.

The particular purposes of the different forms have been forgotten; some adzes hafted by living natives are even set in an inverted position.

The material of the Tubuai adzes (*to'i*) is basalt in various degrees of density. Most of it has been obtained by quarrying. Seale (39) notes,

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A quarry, where axes were broken from the large stones by means of fire and water, was visited—the ground was covered with chips of stone. A number of axes and unfinished bits were found at another quarry or finishing place. . . . The older axes are very rough and seem to be merely an ordinary stone picked up and slightly shaped.

The mention by Seale of the aid of fire should be recorded, in view of the discussion by Best (6, p. 42), Brigham (8, p. 410), and Malo (30, p.77), but should be accepted with reservation on account of the wording. Seale evidently was fortunate in the time of his visit, the selection of exploring routes and the choice of informants. Aitken, coming 20 years later, could learn nothing regarding the location of quarries or of the use of fire in the quarrying process. The "older axes" mentioned by Seale are an axe-like form and several adz-like fragments of weathered, coarsely crystalline basalt—not improbably dike prisms. They were not used as implements. A long dike prism would have been a suitable block for making the slender adz shown in figure 16, *a*. However the use of prismetic blocks can seldom be traced in Tubuai although recognizable in 60 per cent of Rapa adzes.

Method of Manufacture

PREPARATION OF THE ADZ BLOCK

As to the mode of manufacture, Tubuai adzes constitute two classes distinguished by the presence or the absence of pecking. In both classes chipping and grinding are also present. The technic which includes pecking is the most characteristic and the most important in the island.

A study of the incomplete adzes, including some which may have been rejects and others which undoubtedly were in process of being made into good adzes, indicates that in general the preliminary steps in adz shaping was the selection of a fractured stone with at least one flat surface. On this surface, later becoming the front of the adz, the frontal plan was outlined by chipping, as a result of which the rough adz forms were obtained. For some of the wide and thin adzes a single series of blows was sufficient. The resulting fracture sloped inward either because of the direction given to the blows or the radiating force of the percussion, combined with the thinness of the material.

In outlining the deep and narrow adzes more chipping was done. In one adz (fig. 16, *b*) scars near the edge and at each side of the blade front show the result of lateral blows struck horizontally; a few scars on the sides indicate the backward blows, and scars on the base indicate forward and diagonally outward blows along a middle vertical line. This process, if well carried out, produces an adz with a triangular cross section, like that shown in figure 15, *b*; but in most of the long and narrow adzes, a general convexity takes the place of the anticipated angularity.

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In the adz shown in figure 16, *a*, a portion of the upper surface is patinated in a manner suggesting that the block was a dike prism. An attempt has been made to remove the soft surface material by lateral chippings delivered horizontally and by pecking. Otherwise the shaping has proceeded by chipping as in that shown in figure 16, *b* and the complete removal of the patina left for the pecking process.

The next step in the chipping process was the rough shaping of the edge and the bevels. In some adzes the forward edge-bevel was produced in the rough by lateral chippings delivered horizontally (fig. 16, *b*) but for most wide and thin adzes made from large flakes, this was unnecessary. The edge was formed by light chippings delivered accurately in line and in an upward and backward direction. The edge scars remain until the grinding—the last process. In one adz (fig. 22, *b*), the edge scars are on the front of the blade. A few bevels would be rough-formed by a single blow, struck at the edge. However, the pecking process was more generally used for this purpose.

In some adzes the shaping of the tang was accomplished by lateral chipping, in others by pecking. As the pecking process nearly always followed the chipping, the relative importance of these processes cannot be ascertained for all adzes.

Except for the roughing out of the edge the Tubuai artisans appear to have been decidedly backward or careless in applying the process of chipping. In the unfinished specimens where pecking has but partly obliterated the chipping scars, the best accomplishment is a very rough shaping—producing some forms hardly recognizable as adzes. For example in the adz shown

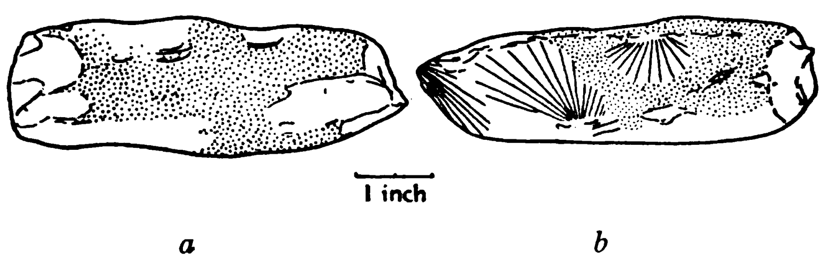

FIGURE 10.—Unfinished adz (No. 6039), chipped and partly pecked, illustrating process of manufacture: *a*, back; *b*, profile.

in figure 10, much pecking has followed the chipping—a clear indication that the progress of chipping the block was satisfactory enough to the particular artisan. The accidental breaking off of the butt, probably, caused the rejection of the block. The concavities of the sinuous lateral margins represent chippings while the convexities are surfaces already reduced by pecking. Likewise in the adz shown in figure 16, *a*, which is nearer completion, the clumsy flaking has almost ruined the block by reducing it too much

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at the middle of the blade, and subsequent shaping has depended almost wholly on pecking.

The abundant flake scars on many of the well pecked and well finished adzes are a further indication of the weakness of the local technic in chipping when followed by the pecking process. On the other hand, when followed directly by grinding the chipping is slightly more accurate. Three adzes (Nos. B. 4580, B. 4597, and B. 4599) are good examples of accurate chipping, although the tangs have been formed in part by pecking.

The quality of the rock of course may be the stronger factor in controlling the presence or absence of the pecking, as is suggested by the fact that three of the five adzes in series C (Nos. B. 4616, B. 4586, and B. 4602) are of extremely fine grained material more adaptable to chipping than to pecking. However, while not common, this material is present in other

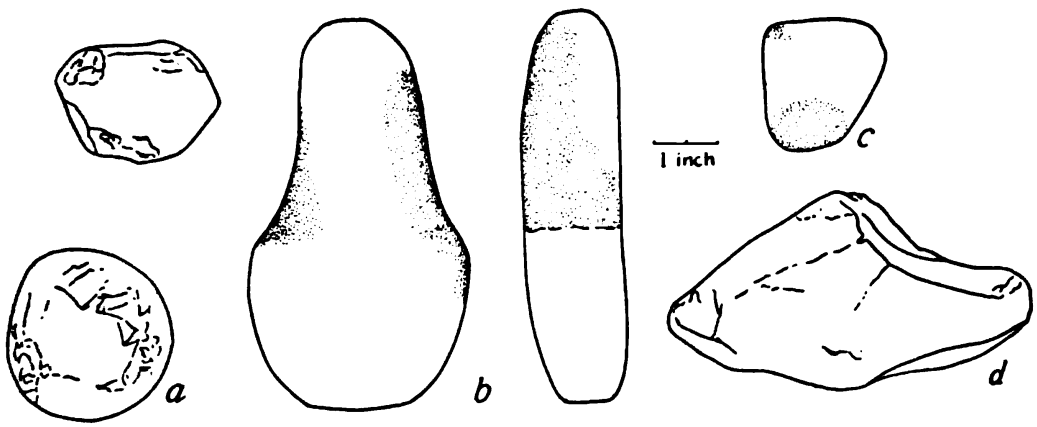

FIGURE 11.—Stone working hammers: *a*, profile (upper figure) and top (lower figure) of hammer used first for chipping and later for pecking (No. 6072); *b*, front (left) and profile (right) of hammer of uncertain use (No. 6077); *c*, hammer used for bruising (No. 6074); *d*, hammer for chipping and pecking from Rurutu (No. B. 4773).

adzes which have been fine-shaped by pecking. On the other hand, two adzes (Nos. B. 4580 and 6035) shaped without pecking, are of material identical with most of the pecked adzes. These considerations indicate that while the kind of stone might explain the occasional absence of the pecking process, there was a technic which dispensed entirely with it, and passed directly from chipping to grinding. The significance of this observation lies in the fact that the distribution of the two technics is not parallel in Polynesia.

PECKING

The pecking process follows that of chipping and is present in several grades. Very rough pecking which must have been applied with heavy blows was noticed on only one adz (fig. 16, *b*) and it is doubtful if it could

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have been applied to a less massive specimen. Gradations are found from this to apparently a very light tapping (analagous to Best's "bruising") which leaves a surface almost as smooth as rough grinding. On any unfinished adz, more than one grade of pecking may be observed. When the pecking is completed, a minimum of grinding is necessary on the prepared surface.

In order of application, the pecking seems in general to appear first on the base, the bevel, or the tang. On finished slender adzes pecking appears

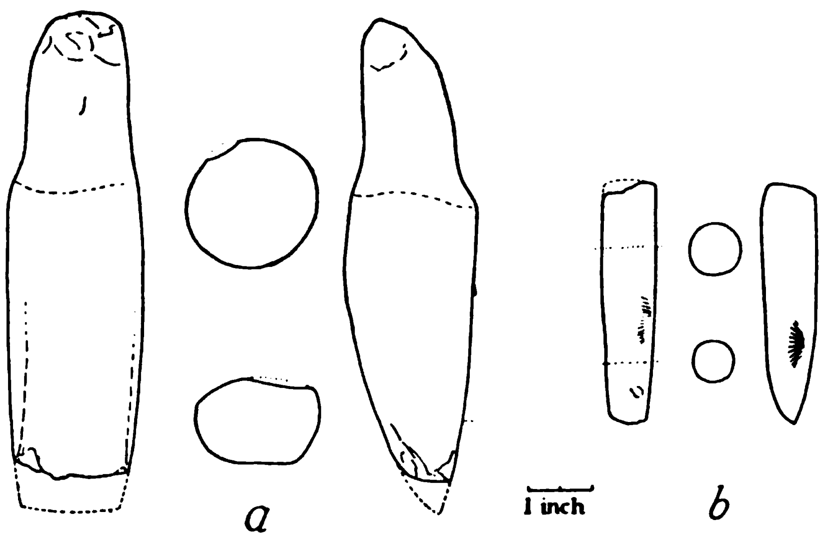

FIGURE 12.—Sketch of adzes of A 1 a Series: *a*, front, two sections, and profile of adz with tang reduced on all sides and receding—perhaps reduction a later addition—grinding on only portions near edge, edge broken and chipped for reforming (No. 6052); *b*, front, two sections, and profile of a chisel or gouge without tang, poll battered through use, surfaces fully ground, no pecking observable—probably absent—(No. B. 4631).

regularly on all surfaces except the edge, and generally the poll, on both of which the scars of chipping remain. On wide adzes also, pecking is regularly distributed, except that little or no pecking appears on the front of the blade.

As a shaping technic, pecking was the most important process in Tubuai. Its relative value is as follows:

1. Reduction of the adz block to an acceptable form following poor chipping. Thus on the adz illustrated in figure 16, *a*, chipping was apparently a failure and the strong convexities of the base at the bevel and middle of the adz were, when the work ceased, under process of reduction by pecking.

2. Formation of the bevel. In finished adzes the bevel may appear to have been shaped entirely by grinding, but pecked, unfinished adzes show clearly enough that the form (including the transverse concavity) is mainly the result of pecking. However, in no adz examined did the pecking reach to the edge, at which the scars of chipping were left until the grinding took place. The high order of skill displayed in pecking is shown by the even lines of the bevel margins.

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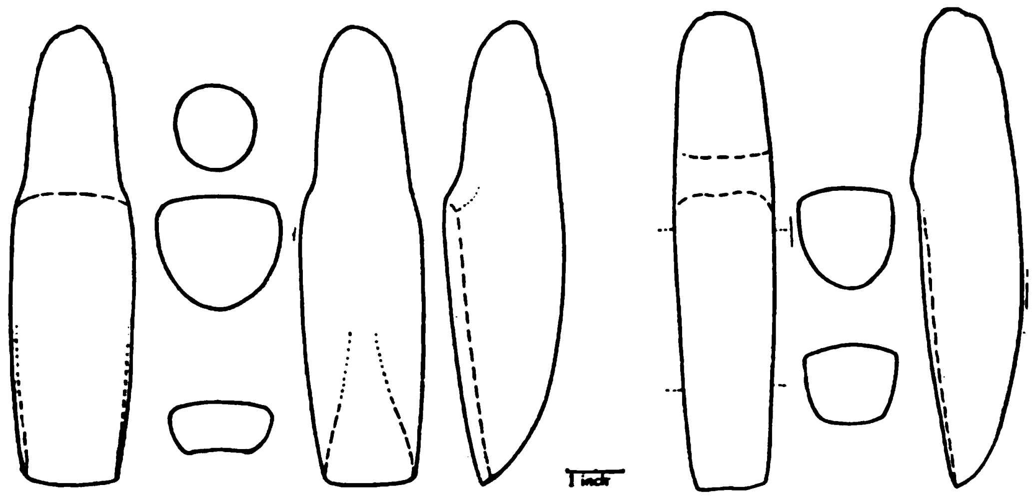

FIGURE 13.—Adzes of A 1 b Series: *a*, front, three sections, back, and profile of adz with flattened ovate cross section, stout form, tang reduced on all sides (No. B. 4622); *b*, front, two sections, and profile of adz with flattened ovate cross section, slender form, complete except for grinding, ridge present at shoulder—a feature of many adzes from the Cook Islands and Rimatara (fig. 31, *c*)—flake scars present at edge and near poll, rest of surface well pecked, good angular margins at front of blade (No. B. 4611).

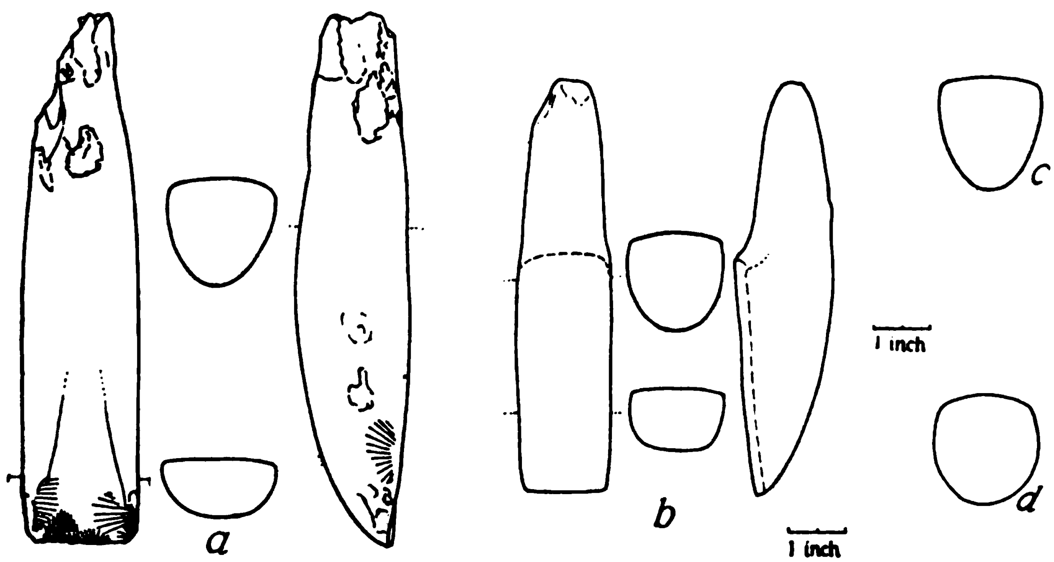

FIGURE 14.—Adzes of A 1 b Series: *a*, back, two sections, and profile of incomplete adz, awaiting reduction of tang by pecking (compare fig. 16, *b*), part of butt recently broken, all surfaces pecked except deep flake scars and vicinity of edge, when finished would probably show taper towards edge (No. 6050); *b*, front, two sections, and profile of adz with flattened ovate cross section, thin form, lateral grinding on tang later reduced by pecking, as to thinness and general lateral parallelism serves as intermediate between A 1 b and A 2 a Series (B. 4610); *c*, cross section of adz with flattened ovate cross section, deep form, subsequent to grinding, back of tang has been flattened by pecking (No. 6051); *d*, subcircular cross section of blade of symmetrical and well made adz, front and bevel well ground and back roughly pecked (No. 6055).

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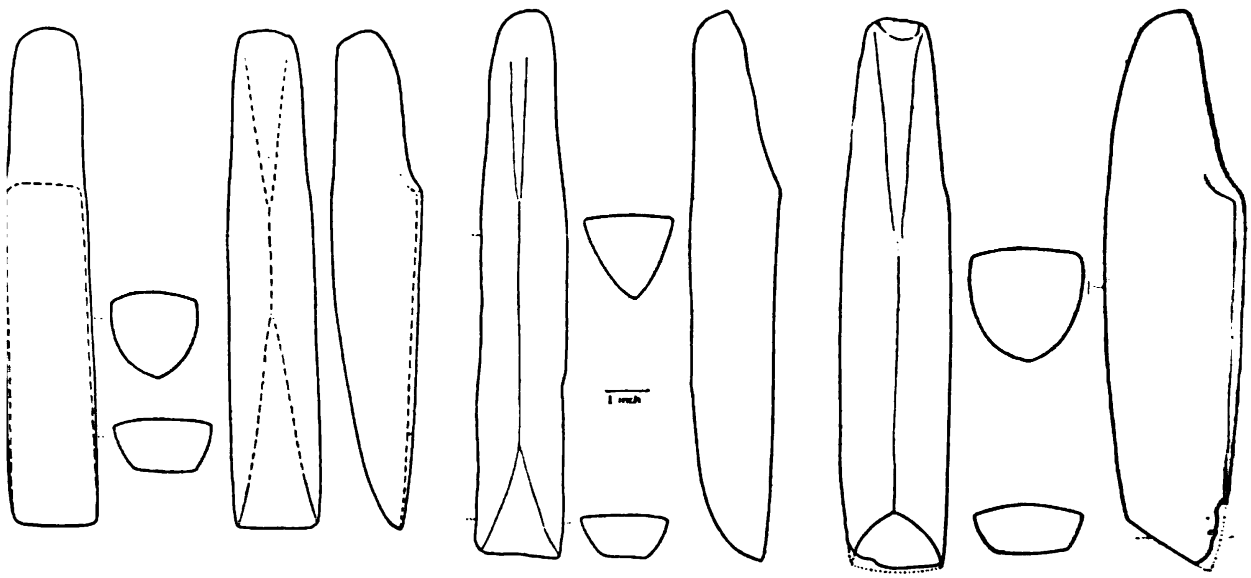
3. Reduction of the surface of the tang at the shoulder. This process is illustrated by nearly all unfinished adzes. In one adz (fig. 16, *b*) it has been begun, in another (fig. 14, *a*), it has not been begun, though the form shows that the adz was intended to be tanged. There are, however, exceptions: thus in one adz (fig. 16, *a*) the tang has been reduced by chipping, followed by pecking on the upper margins to round off the roughness, and in some adzes, particularly among the A. 1 b series, further pecking on the tang has followed the completion of the adz. This is particularly noticeable on adz B. 4622, where the tang probably was roughened to improve the hold of the lashing.



a *b* *c*

FIGURE 15.—Adzes of A 2 a Series: *a*, front, two sections, back, and profile of slender, deep adz with spherical triangular cross section, sides with slight flare towards edge; edge reground, grinding limited to bevel and vicinity and to front of blade, back of tang flattened (No. 6047); *b*, back, two sections, and profile of slender, deep adz showing extreme of triangularity in cross section, pecking complete and adz ready for grinding, back of tang flattened, asymmetry of cross section indicates that good triangularity was difficult to obtain (No. 6054); *c*, back, two sections, and profile of unfinished slender, deep adz, spherical triangular in cross section, with slight convexity of sides, somewhat stout for its class, back of tang flattened, symmetrical and well pecked, but awaits grinding, bevel very short and chin marked, type of bevel is rare or absent in Austral and Cook islands and rare in Society Islands (No. 6053).

The skill displayed in pecking is shown in an adz (fig. 13, *b*), the surface of which, except for the edge, is completely pecked. The flake scars have been almost completely obliterated, the lateral margins of the front and bevel are in good angularity, and the front and sides are but slightly convex. The pecking has produced an even and comparatively smooth surface, so that a minimum of grinding will suffice. The marginal angularity, of course, is the most difficult feature to obtain as the pecking process tends to produce convexity throughout.

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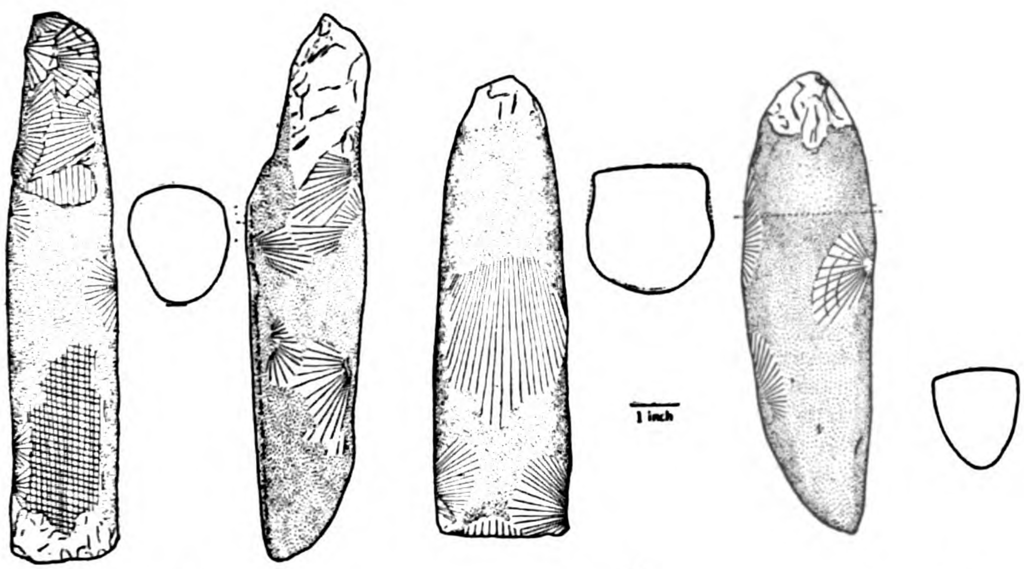
GRINDING

The grinding, in completed specimens, covers the four sides adjacent to the edge, and generally the whole of the blade. In authentic specimens from Tubuai the poll is not ground. The striations of grinding which are too fine to be followed with the naked eye, are either longitudinal or slightly diagonal. On some adzes the grinding began with the lateral surfaces, on others with the front, and on still others with the rearward portion of the



a *b* *c*

FIGURE 16.—Adzes of A 2 a Series: *a*, front, section, and profile of incomplete adz awaiting further reduction by pecking to a form probably like that shown in figure 15, *b*, transverse and longitudinal convexity of bevel and height of shoulder unusual, angular tang shaped by chipping (No. B. 4626); *b*, front, section, and profile of stout, incomplete adz of doubtful class, but nearest to A 2 a Series, block in process of being fine-shaped by pecking, when finished would have been narrower, as in adz shown in figure 14, *b*, pecking was depended upon for shaping of tang (No. 6068); *c*, cross section of slender, deep adz with sides parallel and back transversely convex, blade completely ground, tang broken off at shoulder, in profile similar to adz shown in figure 15, *a* (No. B. 4625).

bevel. But the final grinding was of the edge, when the scars of the edge chips were eliminated. The abundance and distinctness of bevels in transverse concavity indicate grinding on a convex surface—possibly the margin of the grindstone.

It is not improbable that as a prelude to the final grinding, the edge was deliberately flattened by grinding in order to remove minute gaps and to serve as a working guide. This process is used in regrinding dulled edges.

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REGROUND AND REMADE ADZES

Several adzes in the collection studied apparently have been reground or repaired.

Figure 22, *a*, illustrates several adzes, in which the edge had apparently become dulled through use and in preparation for resharpening had been ground squarely across to a thinness of slightly more than 1 mm. If the edge were badly chipped through use, it might be prepared for reforming

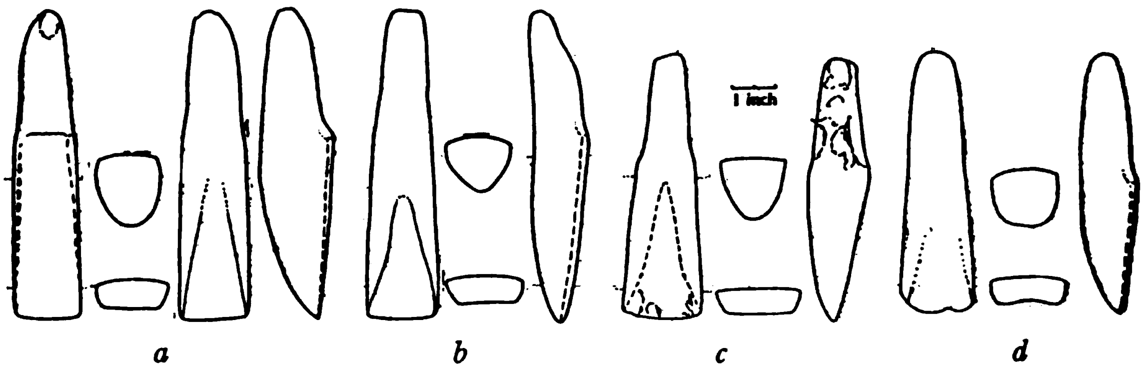


FIGURE 17.—Adzes of A 2 b Series: *a*, front, two sections, back, and profile of adz with flattened, ovate cross section, distinguished from adzes in A 1 b Series mainly by slight flare towards edge (No. B. 3519); *b*, back, two sections, and profile of adz with roughly triangular cross section, tang slightly angular (No. 6044); *c*, back, two sections, and profile of deep adz intermediate between A 1 b and B 2 a Series, edge flattened for regrinding (No. B. 4614); *d*, back, two sections, and profile of medium deep adz intermediate between the A 1 b and B 2 Series, slightly ground all over, bevel pecked in rounded contours leaving transverse concavity, corners of edge blunted, as though used as pecking stone (B. 4594).

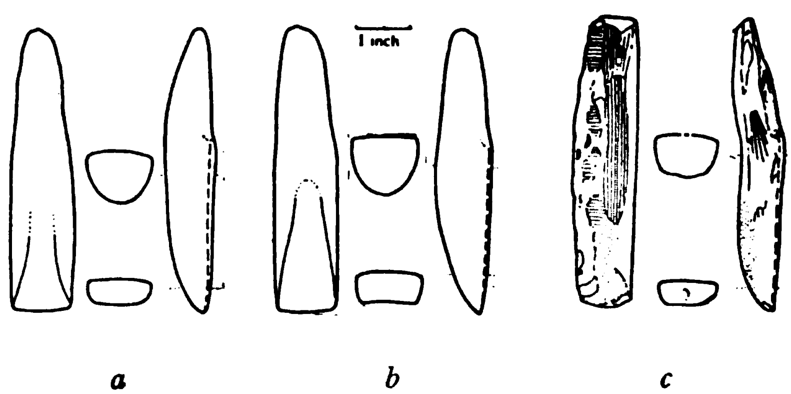
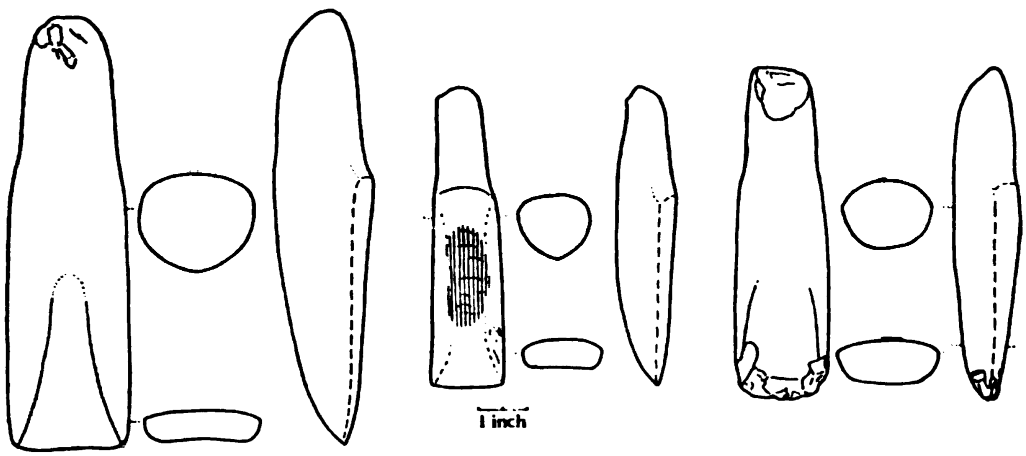


FIGURE 18.—Adzes of A 3 Series: *a*, back, two sections, and profile of adz with nearly semicircular cross section, illustrates high tang and low shoulder, bevel transversely convex without marginal angularity (No. B. 4591); *b*, back, two sections, and profile of adz with cross section semielliptical, illustrates medium tang and low shoulder, bevel transversely concave with good marginal angularity (No. B. 4604); *c*, back, two sections, and profile of incomplete adz, illustrates low and angular tang and low shoulder (No. 6043) (for details of technic see p. 143).

by further chipping transversely in line, as in making new adzes. Adzes Nos. 6052 and B. 4615 illustrate this process. By either process, an increase of the obtuseness of the bevel might be expected. Very few Tubuai adzes are in such condition. Certain adzes are clearly portions of blades broken from long adzes, and on them new tangs have been formed. Five such adzes are listed in series D, four of them showing pecked surfaces, and one, a flaked surface.



a *b* *c*

FIGURE 19.—Adzes of A 4 a Series: *a*, back, two sections, and profile of adz with very broadly ovate cross section, well finished with lateral marginal angularity near edge lost near shoulder (No. 6046), an unground adz (No. B. 4621) is almost a duplicate in form, but marginal angularity is slightly stronger, adz No. 6049 is blade broken from smaller adz of the type; *b*, front, two sections, and profile of adz with broad, ovate-accuminate cross section, median longitudinal portion of front approximately plane, due apparently to long flake scar, portion of which remains, lateral margins strongly rounded by pecking and grinding (B. 4606); *c*, back, two sections, and profile of adz with sublenticular cross section, well ground, biconvex cross section not far from symmetrical, edge broken, probably in process of being reformed (No. B. 4613).

STRATIFICATION OF PROCESS

Pecking is absent or very rare in Hawaiian, Samoan, and Pitcairn Island adzes, so far as well authenticated specimens indicate; it is present, but rare in Tonga and Marquesan adzes; both technics are present, though pecking is dominant, in adzes from Easter Island, the Society Islands, Tubuai, Rapa, the Cook Islands, and New Zealand. In islands where pecking predominates, most of the pecked adzes are superior in form, symmetry and finish to the unpecked ones.

This distribution may indicate different cultural elements in Polynesia. The focus of the pecking process seems to have been the Cook, Austral, or Society islands, where it accompanies a non-pecking process surviving in some marginal areas like Samoa. On the other hand, adzes show that the

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pecking process was important in Easter Island—a marginal point screened, as it were, from the Society Islands, by non-pecking localities such as Pitcairn, Mangareva, and possibly the Marquesas. However, Polynesia cannot be regarded as an isolated area, for in Melanesia, from Fiji westward, both technics were present, but Melanesian adzes are characterized by an excess of grinding, so that the importance of the pecking process, where present, cannot well be determined. The recent archaeological investigations at Guam and adjacent islands indicate a technic in adzes which represents a minimum of chipping and grinding and a maximum of pecking. Any

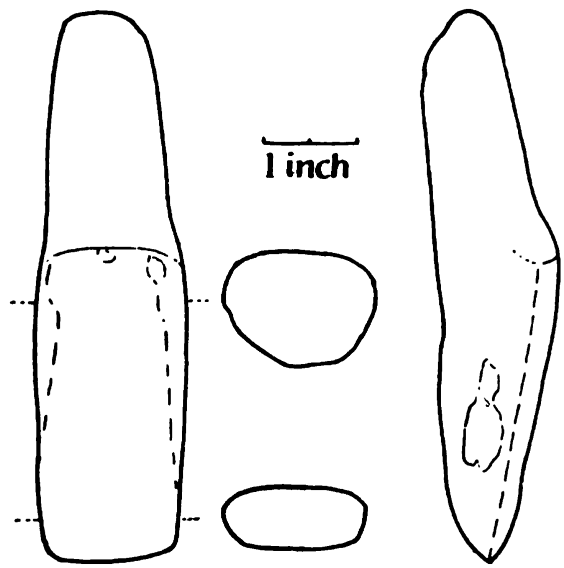

FIGURE 20.—Adz of A 4 b Series, front, two sections, and profile of a possible variant of adz shown in figure 19, *b*, has angular tang, surface irregular, modern grinding present on bevel and other parts of blade, blade front slightly flattened, margins strongly rounded (No. B. 4593).

possible connection of Guam with Polynesia through stone artifacts is of course broken by the fact that the Micronesians had to depend for their adz material mainly on shell, which is less suitable for the pecking than is stone. For the Pacific as a whole, the distribution of the pecking and non-pecking process is insufficiently known. Should it later appear that the distribution is due to local conditions, the relative importance of the two processes in Tubuai should be recorded. Likewise it is well to record the evidence of stratification of the two elements, as shown by some Tubuai adzes.

In an unfinished adz (fig. 18, *c*), the front of the blade shows flake scars, which have been almost ground out, the back shows scars of long flakes and of chips. Grinding on the side illustrated was probably completed while that on the other side which had been formed entirely by chipping, was just begun. Apparently the grinding of the edge and bevel was being con-

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sidered, as the edge had been flattened in preparation. However, on the bevel a rather coarse pecking extends into the already ground surface. It is clear that the intention of the original artisan was to complete the adz by flaking and grinding, and that the pecking was added later by another artisan or at another period. Fine pecking is present on the lower part of the tang.

Adz shown in figure 27, *c* has seen much grinding, but not enough to reduce the flake scars, which show no signs of pecking on their margins. It is

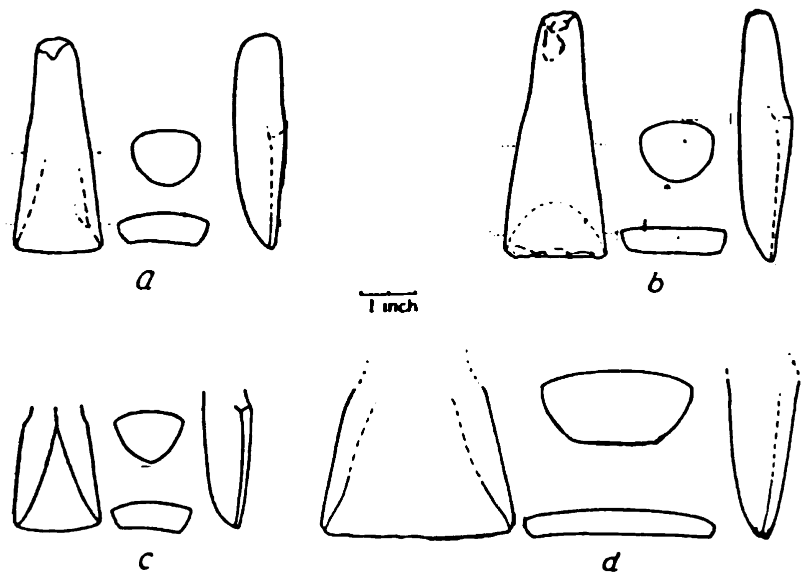

FIGURE 21.—Adzes of B 1 Series: *a*, back, two sections, and profile of adz with broad, ovate cross section, dull polish covering all surfaces except poll, obtuseness of edge and depth of tang suggest characteristics of Rimatara adzes, originally slightly keeled, as with *c*, but angle subsequently reduced by pecking (No. B. 4588); *b*, back, two sections, and profile of variant of *a*, with flattened upper bevel, similar but slightly larger with edge rechipped and bevel pecked for regrinding, another adz (B. 4605), the pecking of which is incomplete, suggests a block for a similar but larger implement (No. B. 4597); *c*, back, two sections, and profile of adz with spherical triangular cross section, hafted in 1902, similar in polish, size, and outline to adz shown in *a*, but with marginal angles throughout (No. 6086); *d*, back, two sections, and profile of adz with quadrilateral cross section, very short and broad, hafted in 1902, polish and bevel similar to those shown in *a* and *c* (No. 6083).

obviously a chipped and ground adz which, after completion, apparently was pecked on one side of the butt to form a tang or to improve the symmetry.

Adz illustrated in figure 24, *c* probably was originally chipped and ground, and later modified by pecking. The front and bevel are chipped and ground; the sides of the blade chipped and partially ground; the tang pecked in front and partly on the sides. One side certainly would have been better pecked on account of its roughness. Similar but less definite examples are adzes B. 4579, B. 4583, B. 4614, and that shown in figure 27, *a*. Other wide adzes

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with triangular frontal plan have had their earlier processes obliterated, but there is enough to suggest that many of them were originally unpecked and

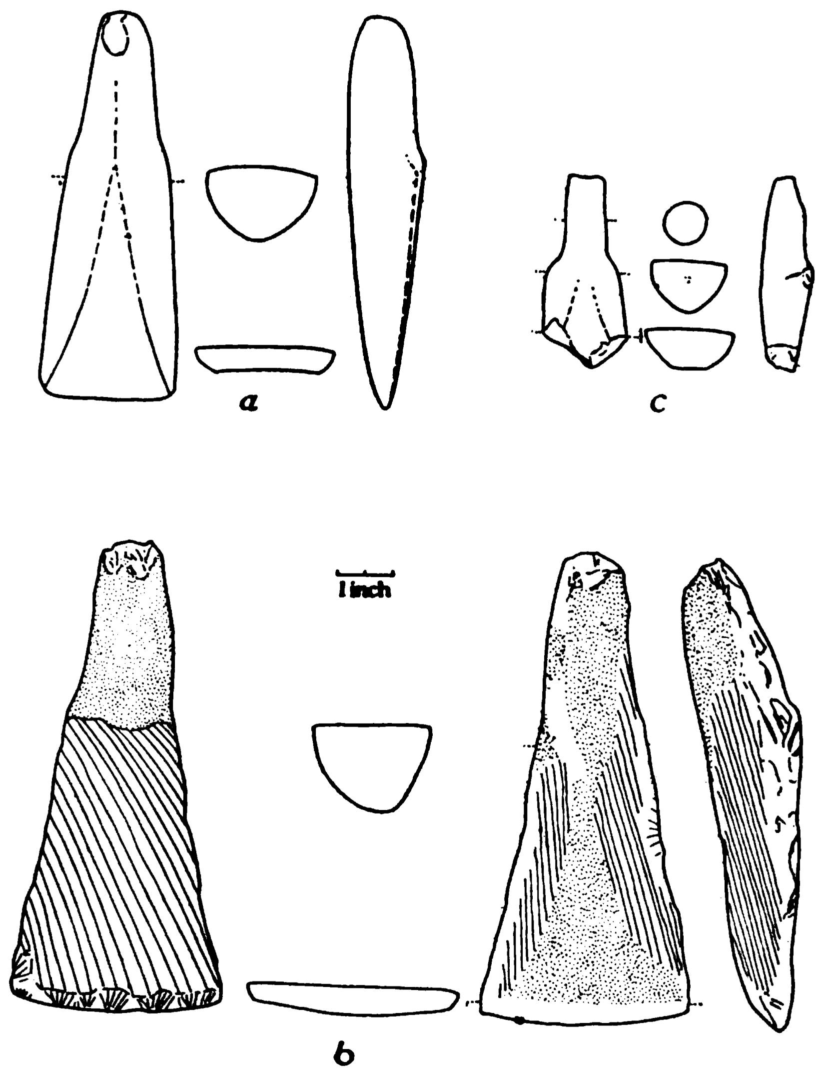

FIGURE 22.—Adzes of B 2 a Series: *a*, back, two sections, and profile of well established form of large and small adzes, front nearly flat with good angularity of margins, sides and back combined convex with occasional but rare suggestion of a keel; edge flattened for regrinding (No. B. 4596), adzes similar in form are Nos. 6042, 6048, B. 3355, B. 4600, B. 4607, and B. 4632; *b*, front, two sections, back, and profile of incomplete adz which when finished would probably differ from adz shown in *a* mainly in angular tang, wedge-like profile would probably follow the grinding, upper edge bevel formed by chipping (No. B. 4624); *c*, back, three sections, and profile of possible variant of adzes shown in *a*, with slender, well-pecked tang (No. 6067).

that the pecking was added to modify the butt and not to shape the blade. Considered with the fact that the adzes in Series C are tangless, shaped without pecking, and though crude in appearance, are efficient tools, it seems

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reasonable to assume that the earlier adzes in Tubuai were unpecked and tangless, or that the butt, instead of being tanged, was bent downward.

On the other hand, the pecked adzes now predominate—an indication of the more recent introduction or adoption of the process—and most of them belong to the long, slender and deep or the sub-fusiform types.

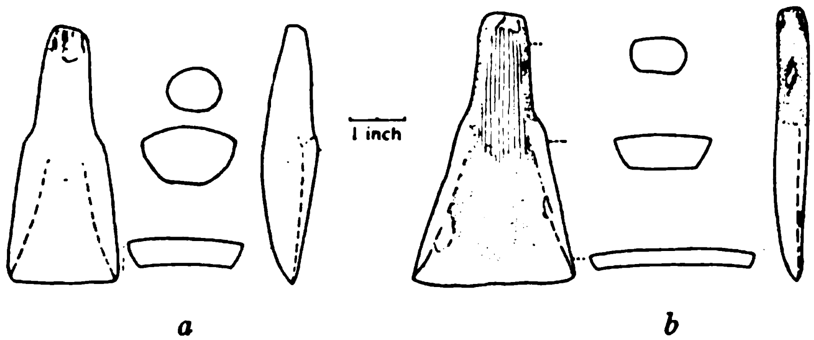

FIGURE 23.—Adzes of B 2 b Series: *a*, back, three sections, and profile of heavily patinated adz showing slight taper of tang in plan (No. B. 4582), similar in form to adzes Nos. B. 4576, B. 4579, and B. 4583, whose bases were either flat originally or have been subsequently flattened by pecking; *b*, back, three sections, and profile of extreme in width and thinness of adzes shown in *a* (No. B. 4575).

USES OF ADZES

Best (6, p. 118) divides the Maori adzes into three general classes: (a) heavy or average sized implements, used in felling and shaping timber;

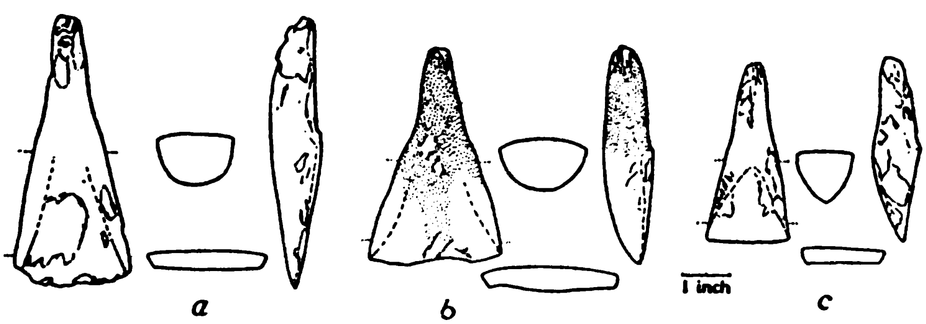

FIGURE 24.—Adzes of B 2 c Series: *a*, back, two sections, and profile of adz with pecking on back, upper portion of bevel, and partly on front of tang, evidence of chipping elsewhere (No. B. 4598); *b*, back, two sections, and profile of adz showing two shallow channels ground on bevel, leaving a pecked portion between (No. 6036); *c*, back, two sections, and profile of well flaked adz with front of tang pecked (No. B. 4587) *a* and *c* illustrate transitions to C Series—comprised chiefly of non-pecked adzes.

(b) lighter tools, used for finer work, such as dressing surfaces of wood; (c) highly finished adzes with ornamental hafts—more important in ceremony and fighting than as tools. There were also chisels and gouges used for incising and possibly for perforating.

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For the tree felling, which seems to have been the heaviest work, apparently two types of adzes were used, a straight, heavy adz of unspecified width, driven across the grain, and a narrow adz cutting with the grain and used for splitting. A scarf, of a hand's width, was made by punching above and below with the first heavy adz and splitting off the intervening portion with the narrow adz (6, p. 132).

In general the Maori wood working processes may be reduced to five: tree felling, rough shaping, fine shaping, finishing, and incising and perforating. A similar range may be assumed for Tubuai, and it is reasonable to assume also that some adzes are more suitable for one process than another. I

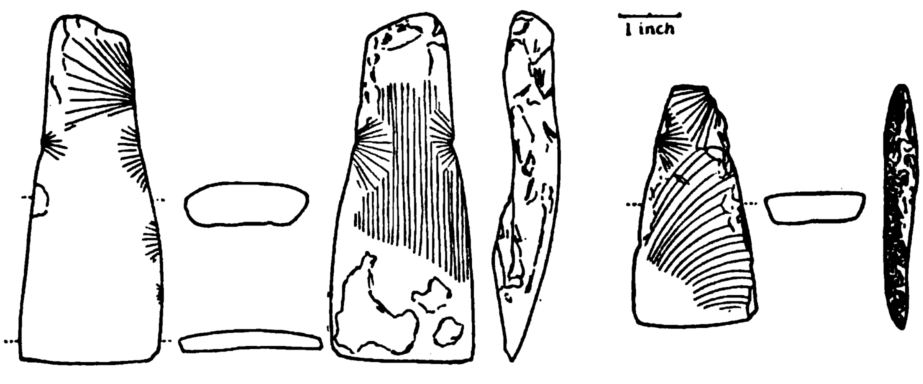

FIGURE 25.—Adzes of C 1 Series: *a*, front, two sections, back, and profile of adz with front of blade convex and well ground, butt rough, light lateral chipping on front and back of butt are aids to binding (No. B. 4616); *b*, front, section, and profile of rock flake shaped by merely chipping in plan of adz, well ground in vicinity of edge and lightly on sides (No. B. 4586). Another adz-head (No. 6085), similar to No. 4586 except for the lateral constriction of butt, is shown hafted in figure 35.

believe that it may be regarded as axiomatic that an adz circular or deep in cross section is more suitable for heavier work than one that is wide and thin.

With the Maori processes in mind, certain Tubuai adzes in the A. 2 a, A. 1 b, and probably in the A. 4 a groups (p. 154) may be recognized as tree felling adzes. In general, the whole adz is very straight and very strong for its length and width on account of the depth and rounded convexity of cross section. Possibly the initial punching was done with adzes of the A. 1 b group, followed, as the scarf grew deeper, by adzes of the A. 2 a group. Adzes of the A. 1 b group seem to be the most suitable for splitting on account of the tapering sides and rather deep bevel. Adzes of the A. 1 a group seem to have been used for the same purpose. Adzes of group A. 4 a contain some stout specimens, but they vary so much in size and cross section of the bevel, that they cannot be consistently grouped for utility identification.

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Though for rough shaping by the scoring method adzes in the A. 1 b group are most suitable, adzes with wide cutting edges would be needed for the reduction of the raised portions left. Quick work could probably be done with the fairly stout specimens in groups A. 2 b and c.

For fine shaping and finishing, adzes of suitable weight, width of blade, and convexity of edge may be found in the B. and C. series. In general I would regard the adzes in the B. 2 a group as adaptable for fine shaping and the rest of the B. 2 group suitable for finishing.

A gouge (fig. 12, *b*) with rounded edge and hollow ground bevel belongs to a type found intermittently through Polynesia; in Hawaii it was used to

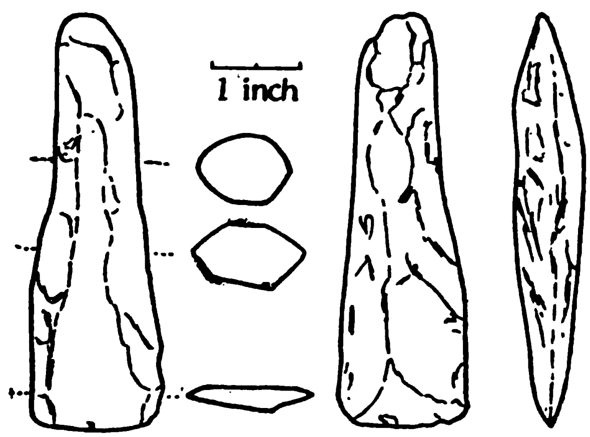

FIGURE 26.—Adzes of C 2 Series, front, three sections, back, and profile of a rough axe-like form, originally with a well ground edge, light and rough peckings on lateral angles of butt suggest a tang (B. 4602).

perforate canoe sides for cord lashings. Abrasions on the poll like those on some Hawaiian and one Rapa gouge indicate the use of a mallet.

Hafted chisels as described for New Zealand by Best (6, p. 115) and for the Marquesas by Linton (28, p. 329) are represented in Tubuai, probably, by such narrow, thin adzes as those in groups A. 3, C. 3 b and c.

ADZ-MAKING TOOLS

In the collection studied are three possible adz-making tools. The first specimen (fig. 11, *a*) is a rough, flattened, but not waterworn sphere of fine grained, very resistant basalt. Its sides have been reduced by use until the somewhat diagonal periphery is almost keeled. Apparently, it had been used for chipping; flake scars as from heavy striking are present. The scar margins, however, have been somewhat rounded through subsequent use, probably for pecking or bruising, but a portion of the original surface still remains on the top. The keel (slightly exaggerated in the diagram) is prominent

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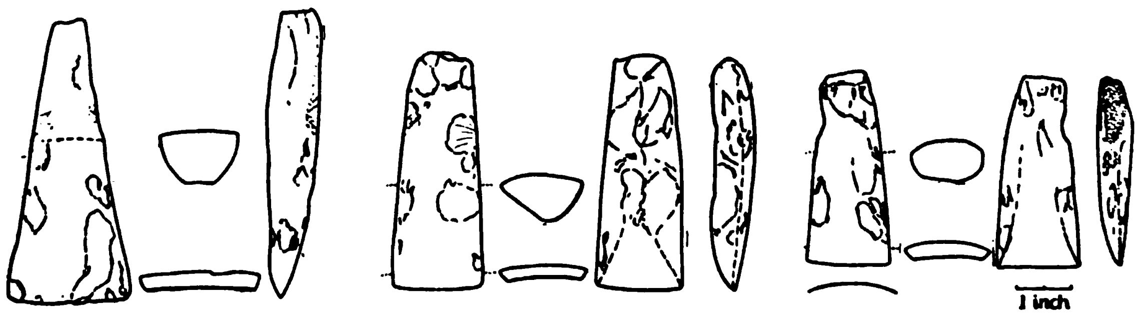
enough to serve for either chipping or pecking. The implement was used for all purposes.

The second specimen (fig. 11, *c*) is a rough cube of granular stone thickly set with small crystals. The top and one side are approximately flat, lie rectangularly to one another and carry their original weathered surfaces. Their margins and the base are convex and battered as though the stone had been used for pecking and bruising.

The third specimen (fig. 11, *b*) is a modification of a thin, oblong waterworn pebble. For a grip, portions of the margins have been convexly re-



a *b* *c*

FIGURE 27.—Adzes of C 3 Series: *a*, front, two sections, and profile of adz well formed by longitudinal chippings, or an adventitious symmetrical flake, flake scar forming bevel nearly three-fourths length of adz, butt near poll triangular in cross section, little pecking on sides and front of butt—enough, with the light chipping, to reduce slightly the angularity of margins, blade lightly ground all over (No. B. 4599); *b*, front, two sections, back, and profile of fairly well ground adz shaped by chipping, profile shows curvature of outline apparently intentional, because made by lateral chippings, all the front of blade and butt ground, but not enough to eliminate flake scars (No. B. 4580); *c*, front, edge, two sections, back, and profile of adz resembling, in plan and technic, that shown in *b*, although ground more, pecking on one side of butt to form tang suggests later addition (No. 6035).

duced by rough pecking, the base has been flattened through use, the other surfaces are unchanged. I have no means of ascertaining the purpose of this implement, but the amount of energy expended in its manufacture indicates that it was of more than casual importance. The rough base which is the striking surface, taken in connection with the well made grip, suggests use as a stone working tool. However, the base, while pitted in a few places as in deep pecking, does not show the expected casual chipping from the flaking blows.

I miss from the collection broken adzes which have been used as battering stones, and also pointed stones which may have served for chipping and pecking. Possibly the stone (fig. 11, *d*), found in the vicinity of a flaked adz block on the neighboring island of Rurutu, represents the chipping and

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pecking implements. It is a natural piece of laminated and weathered volcanic clinker, the pointed ends of which are battered and chipped, while the upper angles are slightly battered. It fits the hand comfortably and is suitable both in size and shape for its assumed purpose. Because of its nondescript shape that it might easily be overlooked among other natural stones.

Adz Forms

The variability of the adzes of Tubuai is marked: the range is from slender sub-fusiform adzes, deeper than wide, to thin flat adzes, widely tri-

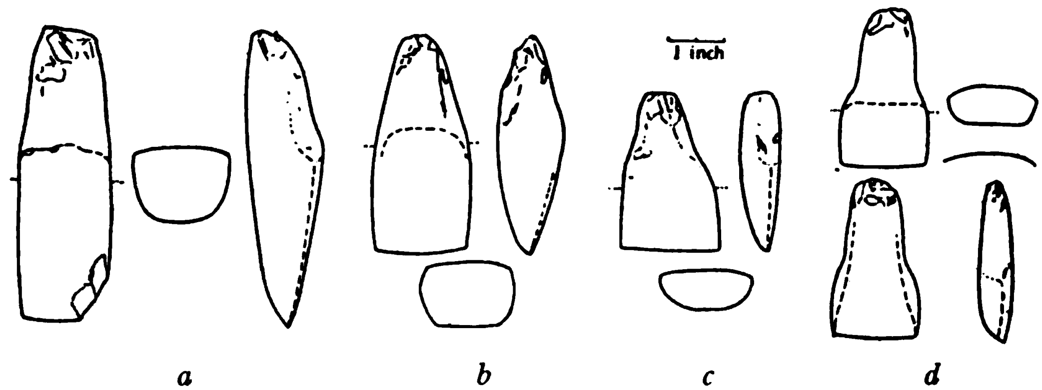

Figure 28.—Adzes of D 1 a Series: *a*, front, section, and profile of remade adz with pecked tang, referable to series represented by figure 14, *b* (No. B. 4612); *b*, front, profile, and section of remade adz with pecked tang, referable to series represented by figure 15, *a* (No. B. 4601); *c*, front, profile, and section of remade adz with pecked tang, referable to series represented by figure 22, *a* (No. 6037); *d*, front, section, edge, back, and profile of small adz, marked concavity of bevel, strongly arched edge, ground on all surfaces except sides of tang, which are reduced by pecking, probably a modification from some form to be found in the A 4 a or B 2 a Series, much secondary grinding present (No. B. 4577).

angular in frontal plan, and as may be observed in types A. and B., into which the bulk of the forms fall, there is a full series of gradations.

In the main cross section, the range is from circular to quadrilateral with convex and backward converging sides. These, however, are extremes, most of the adzes being ovate or spherical triangular, or nearly flat in front with lateral convexity confluent at the back. The quadrilateral forms in general may be regarded as triangular with flattened backs. A feature to be noted is the general weakness of the marginal angle.

In 65 per cent of the adzes examined, the cross section on the bevel shows a concavity, slight to marked. In the other adzes the bevel is straight, slightly convex, or not clearly indicated because of incompleteness of the specimens. Examples of this transverse concavity are found in all groups except the A. 2a Series.

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The section of the butt or tang resembles that of the blade except that the front is much more convex and runs into the sides without angular margins. In some adzes with long bevels, the main cross section is quadrilateral and that of the tang, sub-triangular.

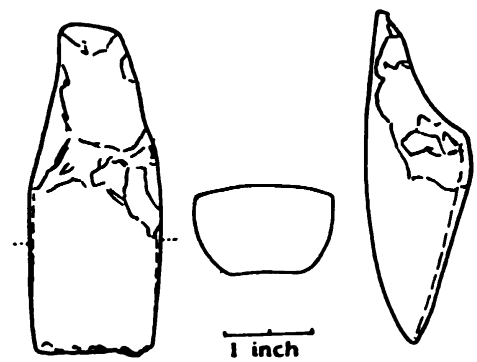

FIGURE 29.—Front, sections, and profile of remade adz with flaked tang, referable to the series represented by figure 14, *b* (No. B. 4574).

In most adzes the edge is curved slightly forward and downward. In about 17 per cent, the degree of curvature is so slight as to require a straight edge to detect it.

The front profile of the blade is slightly convex from shoulder to edge in

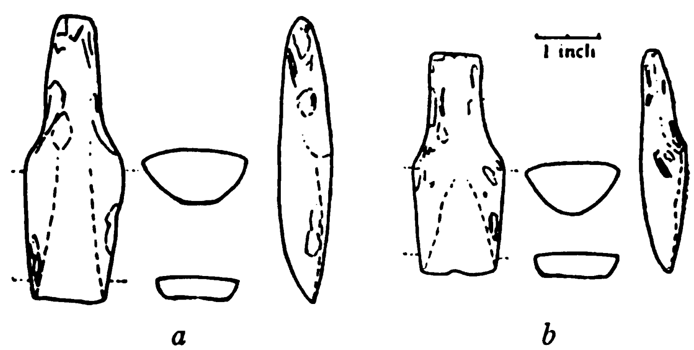

FIGURE 30.—Adzes of D 2 a Series: *a*, back, two sections, and profile of adz with tapering blade, pecking traceable over nearly all the surface, form appears in New Zealand and Cook Islands, bevel is "hollow ground" (No. B. 4603); *b*, back, two sections, and profile of adz with tapering blade shaped entirely by chipping and grinding, little pecking or bruising on front of tang, resembles closely an adz attributed to Aitutaki Island (No. 6038). Both illustrations present greater similarities than do the adzes which they represent, although the adzes differ in technic, kind of stone, plan of bevel, and angle of tang, there is a family resemblance not represented by other specimens from Tubuai.

31 per cent of the adzes. In most however the convexity is limited to the lower portion, while the upper portion is straight in 25 per cent and concave in 44 per cent. In unfinished adzes the concavity may run the length of the blade. In one adz, however (fig. 13, *b*), in which the pecking only has been

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completed, a distinct, though flattened ridge has been left at the shoulder, thus accentuating the concavity.

The rear profile of the blade is characterized by a very long bevel, more or less convex. In some adzes the bevel is longer than the blade, thus transforming the cross section from subtriangular to quadrilateral. The chin at

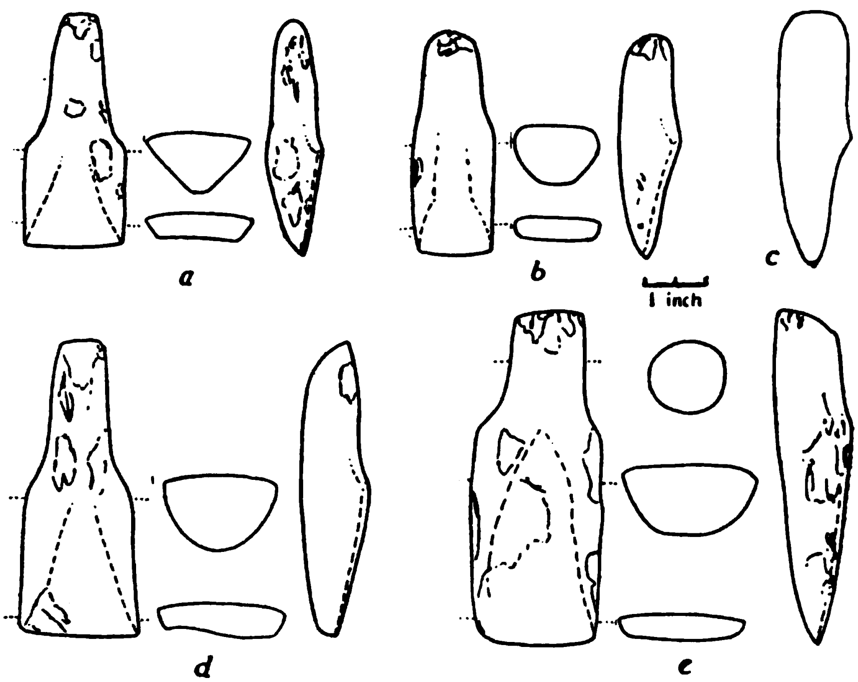

FIGURE 31.—Adzes of D 2 b Series: *a*, back, two sections, and profile of adz with approximately straight and parallel sides, the almost plane sides and front with sharp angularity of margins do not suggest Tubuai work, probably originated in Cook Islands, except for pecking on front of tang and some deep flake scars, adz fully ground (No. 6040); *b*, back, two sections, and profile of adz with approximately straight and parallel sides, would pass for Cook Islands or Rimatara form on account of marked longitudinal concavity of blade front (cf. *c*), though rounding of angle between front and sides near shoulder formed by pecking subsequent to grinding, probably a Tubuai modification of Cook Island adz (No. B. 4590); *c*, profile of adz from Mauke, Cook Islands, illustrating an extreme in the longitudinal concavity of the blade front, and the transverse shoulder-ridge for comparison with figures 13, *b* and 31, *b*; *d*, back, two sections, and profile of adz with approximately straight and parallel sides, of coarse-grained stone and patinated, edge dulled by pecking, as though for regrinding, patination and profile similar to adz shown in figure 23, *a* (No. B. 4595); *e*, back, three sections, and profile of adz with approximately straight and parallel sides, rather rough specimen shaped largely by chipping, tang and parts of sides pecked, probably used with present tang, which in proportion is shortest of all tangs in the Tubuai collection (No. B. 4617).

the conjunction of the bevel and the true back is (with one exception) not noticeable in profile. The lip is seldom marked, so that the profile of many blades is wedge-like.

This back profile of the blade is generally confluent with that of the tang or butt portion and the combined profile is convex in 55 per cent,

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straight in 29 per cent, and concave in 16 per cent of the adzes studied. Most of these have a slight forward bend of the profile towards the poll. Many of the concave specimens are sinuous, and 13 per cent of them have a decided backward bend of the tang. These, however, are not among the

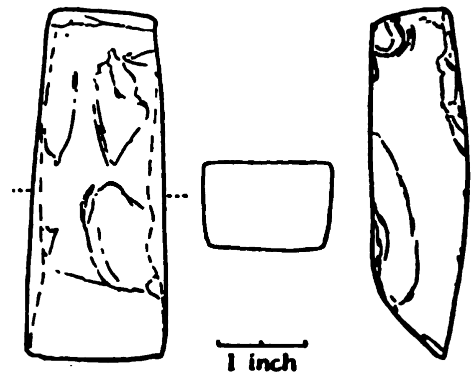
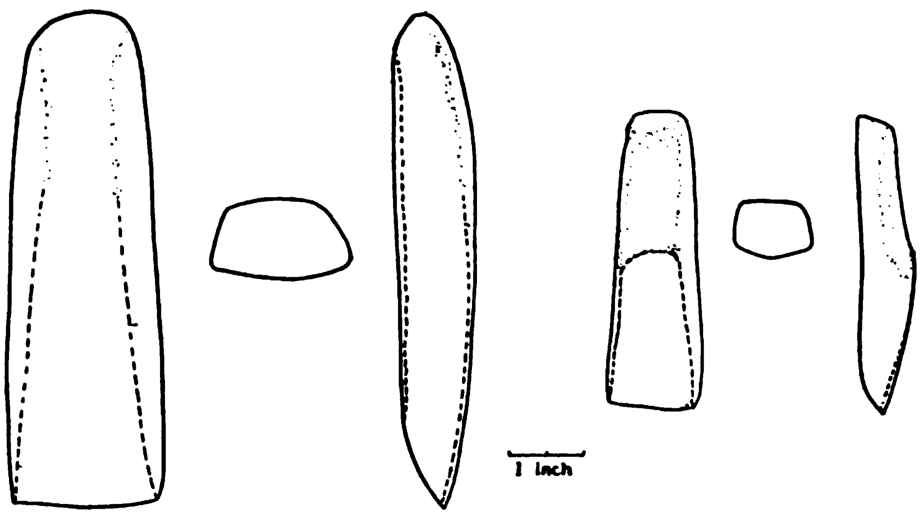


FIGURE 32.—Adz of E 1 a Series, back, section, and profile with subrectangular plan and cross section, no tang, frontal angles of butt slightly chipped, surface highly polished, probably from Tonga (B. 4589).



a *b*

FIGURE 33.—Adzes of E 1 b Series: *a*, front, section, and profile of adz with back wider than front and with transverse convex faces, tangless form, roughly ground all over, light pecking on frontal margins of butt, probably subsequent to grinding, probably Samoan originally (No. B. 4609); *b*, front, section, and profile of adz similar to that shown in *a*, but with tang well formed by pecking—probably a later addition—perhaps originally Samoan (No. B. 4578). Except for pecking and tang, both adzes would be regarded as unusually well finished Samoan adzes; the type is also reported from Niue and Pukapuka, and is approached in Pitcairn, Cook, and Marquesas islands.

best finished specimens. In most adzes the front profile of the tang is reduced at the shoulder, and then further recedes as it nears the poll.

In frontal plan, the lateral margins of the blade are convex in 38 per cent, straight, or nearly so, in 56 per cent, and concave in 6 per cent. Some of

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the adzes with concave margins are incomplete, and probably when finished, the slight concavity would be reduced or eliminated.

The tang generally tapers towards the poll and in plan is reduced slightly in line with the shoulder in all the specimens. In most of them it is due to pecking, following the grinding. In many of the shorter adzes, however, the reduction appears marked on account of the convergence of the

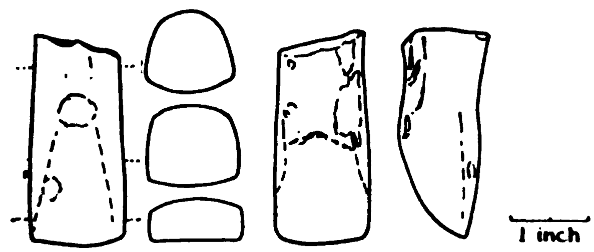

FIGURE 34.—Front, three sections, back, and profile of blade of unpecked adz with sides and front convex in cross section and confluent at margins, almost a counterpart in form, material, and technic of an unpecked adz (B. 9267) found inland on Borabora Island (No. 6064).

sides. When viewed from the back, the reduction is less noticeable, and in most of the adzes the sides of the tang and the blade seem to be but are not confluent.

A tang is present in about 90 per cent of the adzes. None of the polls is carefully finished.

ANALYTICAL KEY

In the following artificial key the Tubuai adzes are classified as to form. Unless specially mentioned, pecking is understood to be present on all the specimens. The numbers refer to specimens in Bernice P. Bishop Museum.

Series A

Narrow adzes or gouges in frontal plan with width of edge and shoulder approximately equal. Sides of blade convex or straight, varying from slight taper to slight flare towards the edge. Tang present on completed adzes; when present, tapering towards the poll. Profile of blade, thick wedge-like with slight preponderance of lip; shoulder generally high. Depth moderate to great (70 to 125 per cent or more of width). Cross sections ranging from circular to subovate, subtriangular or sublenticular. Bevel transversely concave or convex. All surfaces pecked, with grinding on blades of finished specimens.

1. Deep forms, with sides convex in frontal plan and slight taper towards edge. Faces in cross section strongly convex with little or no marginal angularity. Bevel generally transversely concave. Cross sections ranging from circular to flattened ovate.
   - a. Circular to subcircular in cross section. (Fig. 12.)
   - b. Subcircular to flattened ovate in cross section; slight angularity of frontal margins. (Figs. 13, 14.) Intermediate forms in the A 1 b Series are Nos. 6049, 6084, B3353, B4571, B4572, B4608, B4623.

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2. Deep to medium deep forms. Sides of blade approximately straight and parallel or with slight flare towards edge. Flattened ovate to subtriangular in cross section. Lateral marginal angularity of front, slight to marked. Transverse convexity on bevel.
   a. Long and deep forms, many of them keeled. Sides approximately parallel. (Figs. 15, 16.) Intermediate forms in this series are represented by adzes Nos. 6057 and B3354.
   b. Short forms, deep to medium deep; never keeled. Sides in plan straight and with slight flare towards edge. Lateral marginal angularity, marked. Cross section flattened ovate to roughly triangular. This series illustrates intermediates between the A 1 b and A 2 a Series on the one hand and the B 2 a Series on the other. (Fig. 17, *a, b, c, d.*) Intermediate forms are represented by Nos. 6041, 6045, and B4615.
3. Miscellaneous small adzes (possibly tanged chisels) of medium depth, flat in front and with roughly parallel sides. Cross section semicircular or semielliptical. They suggest miniatures of the A 2 a Series, but lack the angular keel and the depth. They are more remote from the A 1 b Series on account of the general flatness of the blade front and the strong marginal angularity. (Fig. 18.)
4. Medium deep forms with a marked transverse convexity of the front. The cross sections are broad ovate, subelliptical or sublenticular, with marginal angles weak or absent. The series seems to be a direct offshoot from the A 1 a Series in wider adzes.
   a. In plan, slight flare towards edge. (Fig. 19.)
   b. In plan, slight taper towards edge. (Fig. 20.)

Series B

Wide and tanged adzes with moderate to marked flare, or subtriangular in plan, with sides generally straight, varying from slightly convex to slightly concave. Depth moderate to slight. Greatest depth less than 70 per cent of greatest width. Profile, thin wedge-like in general, lip occasionally present. Height of shoulder, negligible, to medium. Bevel very long, in many adzes transforming triangular and other sections into quadrilateral. Cross section ranging from broad ovate through sublenticular and spherical triangular to quadrilateral with sides converging backward. Bevel generally transversly concave. Pecking process predominates.

1. Front surface of blade strongly convex. Intermediates between the A 4 and B Series. Thick lipped forms. It is possible that the lip feature is due to regrinding of the edge. (Fig. 21.)
2. Front surface of blade flat or slightly convex. Lip thin.
   a. Adzes of moderate depth and narrow wedge-shape in profile. Cross section ranging from subtriangular to quadrangular. (Fig. 22.)
   b. Thin adzes, in cross section quadrilateral or nearly so. Lateral constriction of the tang rather marked. Shoulder height low or negligible. (Fig. 23.)
   c. Miscellaneous adzes of triangular plan. Lateral constriction of tang inconspicuous. Cross sections various. (Fig. 24.)

Series C

Adzes with tangs and pecking inconspicuous or absent, and depending for shape in part on the adventitious form of the flake. When tang is present, its front surface is in line with blade top. The series might be extended to include Nos. B4587, B 4598, and perhaps others, for which, however, counterparts may be found in other series. In place of the tang, the roughness or curvature of the butt has served for the binding. The roughness seems to be artificial. The amount of grinding varies from that sufficient to sharpen the edge to about half the surfaces of the adz, but is never enough to eliminate the scars of flaking or chipping. None of the adzes is thick. The material of the adzes in Series C 1 and C 2 is a dark, fine grained rock capable of a high polish; the material composing the adz in Series C 3 is coarse grained.

1. Thin flakes, with width of the blade increasing towards the edge, quadrilateral in cross section. (Figs. 25, 35.)
2. Sub-lenticular cross section. (Fig. 26.)
3. Cross sections various. (Fig. 27.)

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Series D

Tanged and wide bladed adzes with sides of blades tapering, straight and parallel or with very slight flare. Thin to moderately deep. Cross sections various.

1. Re-made adzes in which tangs have been made on parts of blades with good edges. Cross section quadrilateral.
   a. Pecked tangs. (Fig. 28.)
   b. Chipped tang. (Fig. 29.)
2. Tanged adzes, generally well made, and unique as to form. Some may be importations—ancient or modern.
   a. Tapering blades, with good marginal angularity of front and bevel. (Fig. 30.)
   b. Adzes with approximately straight and parallel sides. (Fig. 31.)

Series E

Adzes, quadrilateral in cross section, with back about equal to or wider than front. Bevel, short; chin, distinct. Importations into Tubuai.

1. Marginal angularity marked in cross section. Probably no pecking originally.
   a. Subrectangular in plan and cross section. No tang: frontal angles of butt slightly chipped. Surface highly polished. Probably from Tonga. (Fig. 32.)
   b. Back wider than front: transverse convexity of faces. Probably from Samoa. (Fig. 33.)
2. Sides and front of blade convex in cross section, and confluent at the margins; much ground; pecking not recognizable. Probably from Borabora. (Fig. 34.)

The classification of adzes attributed to Tubuai shows that there is an amount of diversification in form unusual for such a small island. Part of the diversity is undoubtedly due to the importations from other islands, listed in the E Series, suspected in the D Series, and possibly in the B. 1 group. But the diversity is great even among adzes accepted as of Tubuai origin on the basis of frequency of occurrence, the presence of specimens unfinished, or of unattractive form and finish.

The most important group numerically is A. 1 b, while the A. 2 and B. 2 Series include many forms. All the adzes in these groups are well made and attractive in appearance, and thus likely to be selected first by the amateur collector. Aitken reports that most of the specimens in a large private collection in Tubuai, belong to groups A. 1 b and A. 2 a.

While the proportions of the various types will probably not be known until cultivation with deep ploughing methods are applied in Tubuai, it may be assumed that the C. Series will be larger than at present, though I cannot point to comparisons outside Tubuai on account of lack of material. It is significant that in comparison with other wide adzes examined from Rimatara and Raivavae, as well as from Tubuai, adzes of the C. Series are distinctly crude in form and finish, although efficient tools. The series as shown by Linton (28, p. 327) may represent an earlier culture in which untanged adzes predominated. It has left but little recognizable effect on the general run of the Tubuai adzes.

In general features, the Tubuai adzes approach those of the Cook Islands most closely than other islands. For example, the frequency of the plain type of unspecialized tang, the long bevel, and the hollow bevel,

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the absence of a chin, the longitudinal concavity of the blade front, the inverted spherical triangular cross section, are distinctly reminiscent of the Cook Islands. For these features, a stepping stone exists in Rimatara, the westernmost of the Tubuai Islands. Groups A. 2 a, B. 2 a, and D. 2 include specimens which if found in Cook Islands would probably be accepted as originating there.

However, there is a mild suggestion of influence from the Society Islands, in the occasional bent tang and the inverted triangularity of cross section. In Mangaia the bent tang appears on some ceremonial adzes, but not on others.

The triangular cross section, with plane faces and good marginal angles (a characteristic of the highest developed types in the Society Islands) is present, though rare in Tubuai, where the adz faces are convex and the marginal angularity weak. In Cook Islands the convexity is marked, as is also the marginal angularity. It is suggested that in this respect the Society Islands influenced both the Cook Islands and Tubuai, but that the influence of the Cook Islands was stronger. This suggestion is supported by other features of Cook Islands and Tubuai adzes mentioned which are not characteristic of the Society Islands.

In these respects I find that the island of Rimatara, west of Tubuai, inclines to the Cook Islands, while the island of Raivavae on the east inclines to the Society Islands.

On account of their narrow distribution and nearness to the place where their prototypes are found, the features discussed may be regarded as the latest to affect Tubuai. It is probable that they were superposed on or modified earlier types.

A consideration of Series A and B, comprising most of the authentic Tubuai adzes, draws attention to the fairly easy transitions between a subfusiform type represented by A. 1 a and a thin, flat type, subtriangular in plan, as B. 2 b or B. 2 c, and to intermediate steps shown in groups A. 1 b, A. 2 a, A. 2 b, A. 2 c, and B. 2 a. Apparently Series A. 4 a is related independently to A. 1 a. The transitional forms include the full equipment necessary for rough Polynesian carpentry—the deep, narrow, stout adz for roughing out, the thin, broad adz for finishing and desirable intermediates. The whole series, however, is bound together by the presence of a greater average cross sectional convexity than is to be found elsewhere in the Austral Islands, or their nearest neighbors, Cook and Society islands. In fact, it seems to represent a blending of two or more distinct types after long contact, under the influence of the subfusiform type together with such modifications as the triangular cross section.

The marked increase in width towards the cutting edge of the Tubuai adz, subtriangular in plan, is rare in Polynesia. It is approached in several

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places, including Cook Islands, and is equalled or exceeded in adzes or other cutting implements in Pitcairn Island, Easter Island, and Hawaii. Evidently the Tubuai type is not isolated. A native manuscript history alleges the descent of Mangarevans from Rarotongans, and a migration to islands claimed to be Pitcairn and Easter. It may be significant that among the adzes described by Brown (9) from Pitcairn, the extremes of the Tubuai series are to be found but of such large and unwieldy size as to be suitable only for ceremonials. The intermediate forms are approached in the Cook Islands where, however, the extremes of the Tubuai series are not reached.

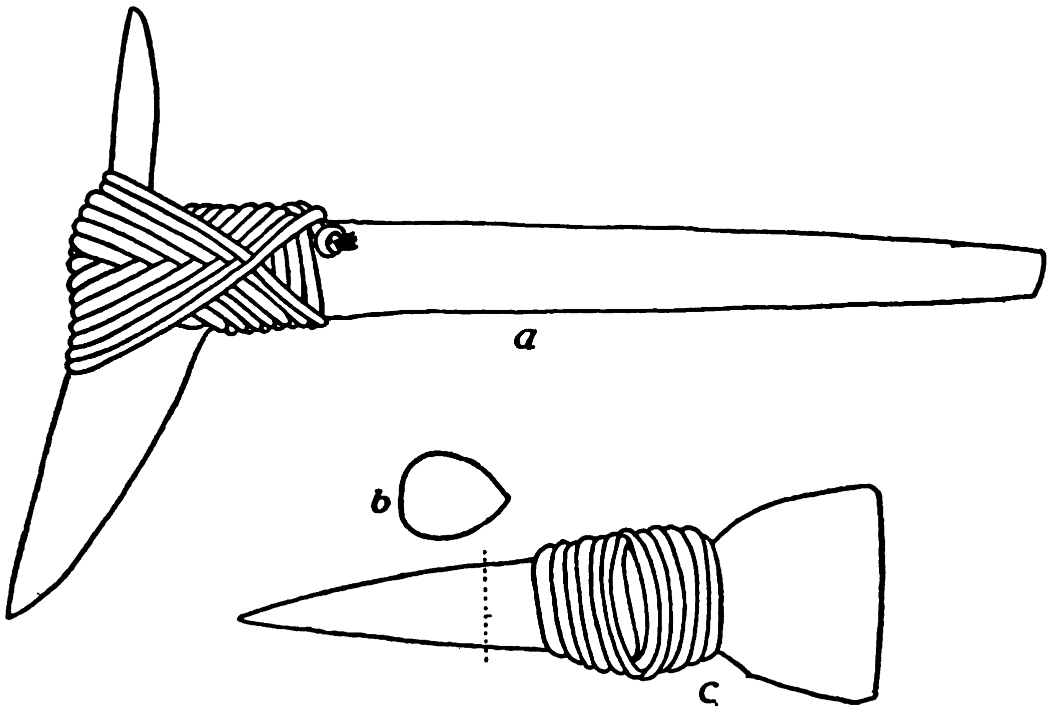

FIGURE 35.—Composite of four adz hafts collected in 1902, with adz head of No. 6085 (cf. fig. 25, *b*): *a*, profile; *b*, section of spur; *c*, front of adz. Lashing and grip identical in the four, variation being in angle of spur, no forward extension of haft, consequently lashing less in amount and complication of design than in figure 36.

Evidently migrations of types affected Pitcairn, Tubuai, and the Cook Islands and the types were later blended in Tubuai and Cook Islands but not in Pitcairn, which, as is well known, had been abandoned by the Polynesians when first visited by Europeans. It is doubtful that such a feature would be independently evolved on Tubuai. It more likely represents a survival of forms introduced into Polynesia or a survival of earlier Polynesian forms.

Hafts and Lashings

No authentic ancient adz hafts from Tubuai are available to me for study, but 13 hafts made in modern times show features from which certain char-

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acteristics of forms and lashings may be deduced. Of these 13, 3, described by Caillot (13), were collected in 1900; 4 were collected in 1902; 2 in 1921; and 4 constitute the "Young Collection" (date unknown). Of the 4 in the Young Collection, 3 (fig. 37) are localized as from the Marquesas Islands, and 1 as from Raiatea, but similarities in shape, lashings and heads are sufficient to class them with hafted adzes from Tubuai.

The 9 hafts definitely known to have originated in Tubuai fall into three groups of forms correlated with the time collected. The specimens of each

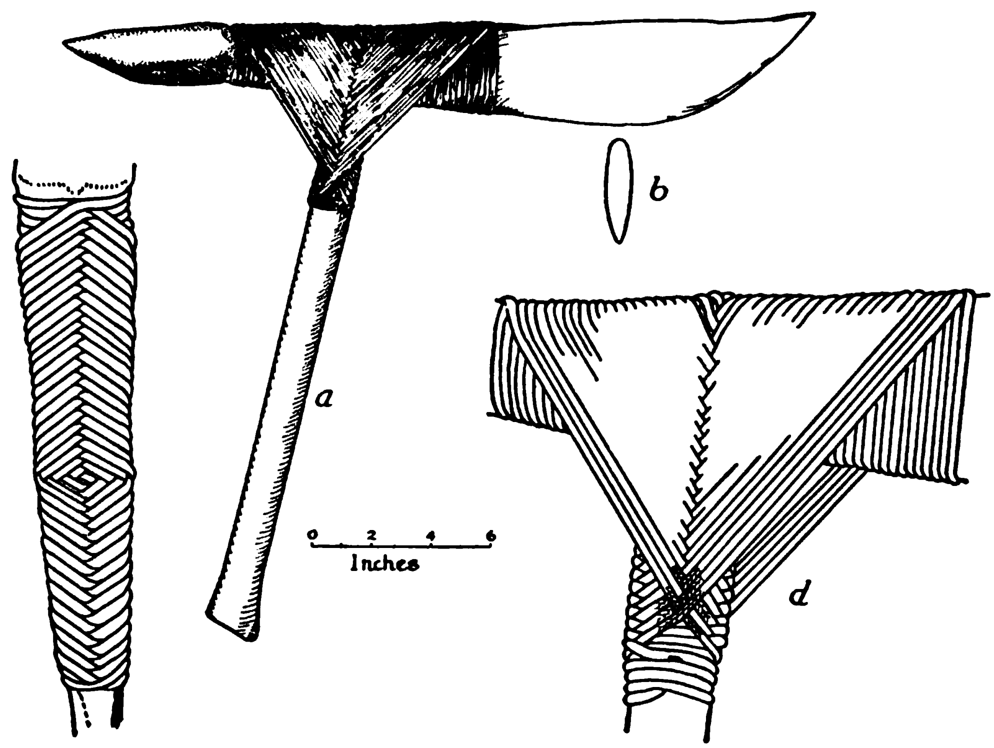

FIGURE 36.—Composite profile and detail of lashing of two hafted adzes collected in 1921: *a*, profile of hafted adz; *b*, cross section of spur; *c*, and *d*, details of lashing, front, and sides (Nos. B. 4571, B. 4572). The impractical over development of spur represents a modern native's idea of ancient form, great amount of lashing is an accompaniment to forward extension of haft.

group resemble each other so closely that doubtless each group represents the work of one man. The hafts are alike in the material used (*ati,* or tamanu: *Callophyllum inophyllum*), in the presence of a prominent spur extending rearward of the shaft, and are closely similar in the method of binding. A deep channel to accommodate the tang, and extending part way along the top of the haft, characterises the 1902 (fig. 35) and the 1921 (fig. 36) groups (figs. 35, 36), and is probably present in adzes of the 1900 group. The chief points of difference are the absence of a forward extension of the haft and the short shaft tapering towards the grip in the 1902 group; the haft extend-

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ing forward of the shaft, and the long shaft with sides either parallel or flaring slightly towards the grip in the 1900 and 1921 groups.

It is not improbable that the small headed hafts of the 1902 group and the larger headed ones of the 1900 and 1921 groups represent two utility types: the first probably designed to be gripped by one hand, and the second by both hands. In the 1902 group three of the heads are small.

The conventional shape of the rearward spur of Tubuai hafts cannot be determined by the specimens examined. It probably was subject to much variation, but the repetition of a spur on all the adzes marks its presence as an established characteristic. However, the spurs of the 1921 group (fig. 36) are so exaggerated and impractical of use that, as Aitken recorded in his notes, "the artisan was using his imagination too freely." It is not impossible that these adzes represent ceremonial forms, although entirely different from the ceremonial adzes from Mangaia Island on the west and Ravaivai on the east. Surface ornamentation is absent from the hafts known to have originated in Tubuai.

The hafts attributed to Raiatea and the Marquesas resemble most the 1902 group. They differ from those collected on Tubuai mainly in the continuity of the channel and the presence of ornamentation effected by burning or incision (fig. 38). A rudimentary forward projection is present on one of them (fig. 37, *c*).

The lashings in the 1900, 1902, and 1921 groups are alike in materials and method, though differing in appearance and extent. All the lashings are of coconut fiber, braided three-ply. In binding the adz heads onto the haft, the tangs of the 1902 and 1921 groups were first wrapped in cloth. The heads of the other adz hafts (figs. 37, 38) are unwrapped. The lashing in the 1902 group is a four-loop cycle; whereas that in the 1900 and 1921 groups is a six-loop cycle, the additional loops inclosing the forward extension of the haft, and, for symmetry, the spur. The lashing is theoretically winding, always onward, without overlapping the preceding course. Technically it is a series of single half hitches.

The 1902 group shows the simpler method of lashing (fig. 35):

In this, two or three turns are made with the braid around the tang and the crotch of the spur in order to hold the head in place, then follows a cycle of six movements beginning at the crotch of the rearward spur: (1), over the tang, passing to the front of the initial winding; (2), down under the crotch; (3), around the front of the shaft; (4), over the tang passing at the rear of the previous windings; (5), down to the front of the shaft; (6), around the back of the shaft under the crotch. There are thus a series of four loops, which if possible to represent in diagram would show the first and third at the extremities, and the second and fourth in the middle placed on one another. Laid in a plane, only three loops would show. In this type of lashing,

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the shaft alone is completely enclosed in the winding, not the head nor the spur, so that the adz is held in place solely through the downward pressure exerted by the binding. The binding itself has an element of ornamentation in the symmetry and evenness of the four series of braid crossings; at the front and back of the shaft and on both sides.

The lashings of the 1900 and 1921 groups are identical in method and differ only in degree. However, as compared with those of the 1902 group, there are two additional movements following the first and the fourth, in which loops are passed around the tang and the forward member of the haft in the first, and around the spur in the fourth. These loops diagrammati-

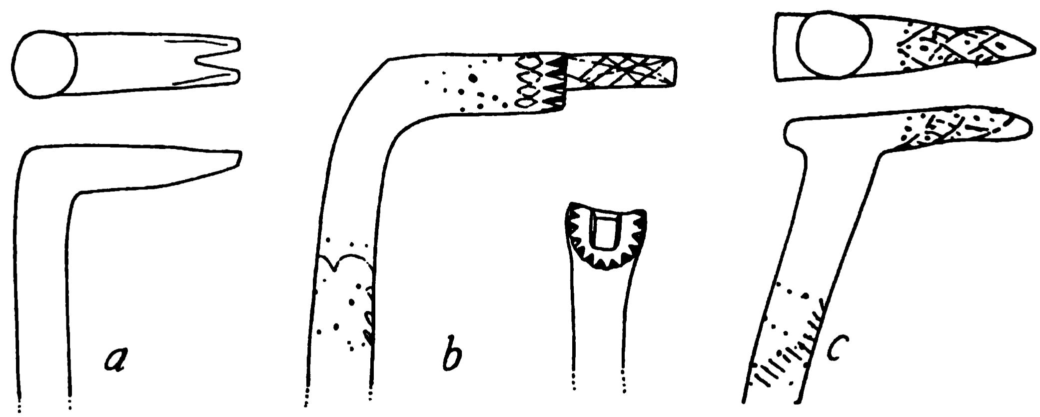

FIGURE 37.—Adz hafts attributed to Marquesas but probably from Tubuai: *a*, lower and profile view of spur (No. B. 3353); *b*, profile and rear of spur, showing burned and incised designs (No. B. 3354); *c*, lower and profile view of spur showing burned designs (No. B. 3355).

cally represented would adjoin the extremities of the lashings in the 1902 group, and would add two series of crossings in line at the top of the haft. The lashing is theoretically stronger than that of the 1902 group because of the direct binding to a projection made possible in the type of haft.

The four adzes in the Young Collection have no packing around the head. The lashings (fig. 37 *a, c*) are identical with those of the 1902 group. That of the haft in figure 37, *b* follows the same movements for six complete cycles, after which there are six cycles of a simpler three loop series enclosing the spur and the shaft, and crossing at the crotch and the front of the shaft. The lashing of the haft in figure 38 follows the 1902 style for five cycles, after which follows plain winding along the spur for ten cycles.

From the evidence in hand it appears that there were two types of hafts in Tubuai and one general method of binding. Both types of hafts are characterized by a prominent rearward spur, and are differentiated by the absence or presence of an extension forward of the shaft. The first type suggests analogies with the few hafts available from the Cook, Society, and

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Tuamotu islands, but not elsewhere in Polynesia so far as known. The lashings resemble those of the Society and Cook islands, where, however, there are additional windings not represented in the Tubuai specimens.

The second type of haft, with the extension forward of the shaft is probably the older of the two. This type, with the spur shortened or absent, is widely distributed in Polynesia outside the south central division.

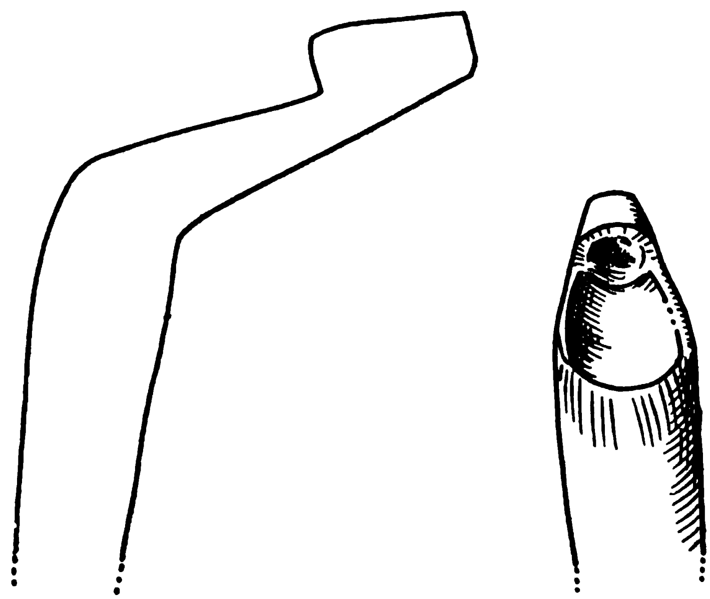

FIGURE 38.—Haft attributed to Raiatea, but probably from Tubuai, profile of adz haft and front view of spur showing shallow groove (No. B. 3519).

Conclusions based on a study of the hafts are inconclusive on account of the scarcity of material from the central and eastern Pacific regions, but as far as present knowledge extends they are not out of accord with those reached in regard to the adz heads (p. 156).

POUNDERS

The pounders (*penu*) from Tubuai in Bernice P. Bishop Museum are represented by four food pounders, two of coarse celled coral (*Orbicella sp.*), one of fine celled coral, and one of coarsely crystalline basalt. In addition to these pounders, used for making poi, there are two which, because of their size, may be regarded as medicine pounders.

All the poi pounders observed by Aitken in use in Tubuai are of *Orbicella* coral. They are remarkably uniform in size and shape. In form they range from pounders with body strongly flaring downward, base deeply convex and lugs fairly upright (fig. 39, *a*) to those with body of slight flare, base less convex, and lugs more horizontal (fig. 39, *b*). The form shown in figure 39, *a* is more common. In none do the lugs of the bifurcated head drop below

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those shown in figure 39, *b;* in some they are more erect than those shown in figure 39, *a*. In horizontal sections, the pounders are circular at the base and elliptical or circular at the neck. The chief characteristics are: (*a*) the great diameter of the base, ranging from 66 to 100 per cent of the height; (*b*) the marked concavity of the body and marked convexity of the base in vertical outlines; (*c*) the angularity between body and base; (*d*) the bifurcation of the head and the upward bend of the prongs or lugs.

The natives state that these pounders are readily cut into shape from the soft, fresh coral masses, but that the material becomes more resistant and more brittle when dry, and consequently must be moistened from time to time to prevent cracking. The shaping today is done with metal tools.

In use, the *Orbicella* coral pounder is held with one hand encircling its body; the other hand being employed to fold back the spreading sheet of poi. The adaptability of the *Orbicella* coral pounder for making poi, particularly taro poi, is worthy of note. Because of their thick circular walls and weak septae the cells of this species of coral are remarkably tubular in form. They attain diameters of 7 mm. and are contiguous. The somewhat radial growth of the cells ends at the surface of the hemispherical base of the pounder, so that the surface looks more like a coarse grater than that of a pounding implement. The slippery taro yields more readily to reduction by such a surface than by the smoother surface of pounders made of stone.

Of the *papahia* (utensils on which poi is made), the only kind to be seen today in Tubuai is a four-legged low stand, neatly hewn out of a single block of *ati* wood. The pounding surface is 6 to 9 inches above the ground and measures 18 by 20 inches in plan, the corners being well rounded. It may be slightly convex when new, but becomes concave after long use. The lower surface is strongly convex and meets the pounding or upper surface at a fairly thin edge which overhangs the legs by an inch or two. In profile, the *papahia* suggests the west-central Polynesian kava bowl, which possibly has influenced its form.

An examination of the pounders in hand suggests that the mode of *Orbicella* coral growth has influenced their shape. The more or less spherical masses of coral are formed through the radiation in divergent curves of the tubular calices, the focus of growth being at the base of the mass. The concavity of the sides of all the pounders approximates the course of the calices and in many follows it absolutely. This may, of course, be only incidental, as strong concavity of outline is a feature of some stone pounders from the Society Islands, and is characteristic of those from the Marquesas and Hawaii. Concave sides might be regarded as a normal feature for the particular type of implement. On the other hand, the strong convexity of the base on such broad pounders is limited to those made of *Orbicella*

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wherever found, and of stone in Hawaii—a region too distant to imply common origin. This convexity is characteristic of the surfaces of corals growing in massive form, such as an *Orbicella*. A pounder from Rimatara still carries on its basal surface traces of the original surface of the coral mass. It seems safe enough to assume that the basal convexity of the *Orbicella* pounder is largely due to that of the original coral mass.

To the same influence may be traced the angle of the lugs of the *Orbicella* pounder. The bifurcation of the head is characteristic in stone pounders

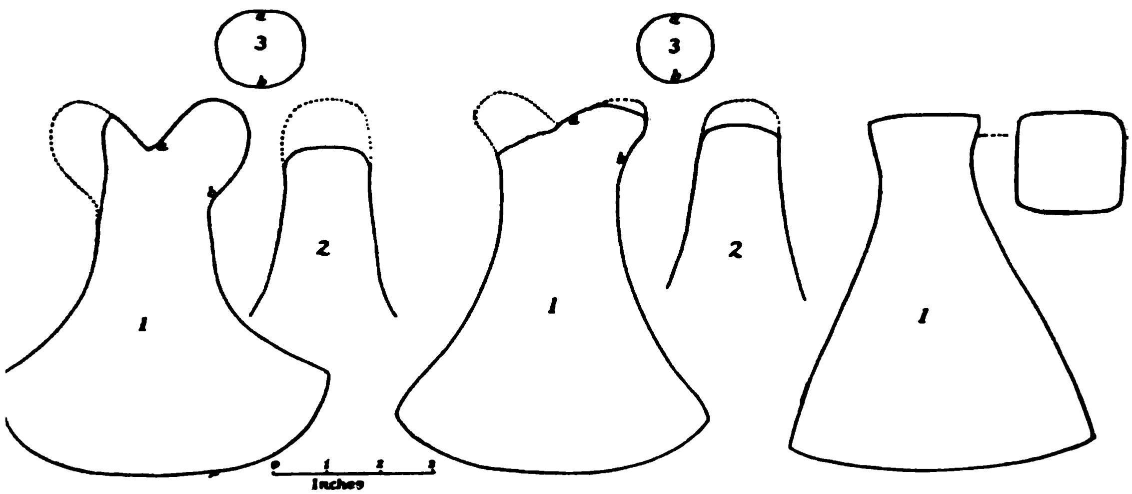

FIGURE 39.—Tubuai poi pounders: *a*, well worn pounder of coral—1, vertical section, front view; 2, vertical section, side view; 3, section of prong, horizontal section of base roughly circular, of neck elliptical, weight 4 pounds, 5 ounces (No. 6080)—; *b*, slightly worn pounder of coarsely crystalized basalt—1, vertical section, front view; 2, vertical section, side view; 3, section of prong, horizontal section of base circular, of neck elliptical—; *c*, unused pounder of coral, head roughly square in plan and plane on top, base and neck circular in horizontal section, weight 3½ pounds (No. 6079).

from the Austral, Cook, Society, and Marquesas islands, but the outward strong inclination of the *Orbicella* lugs is exceptional. In Raivavae, the island nearest to Tubuai, the lugs are comparatively horizontal (fig. 40, *c*) and might well have served as thumb grips if the pounder were grasped in two hands. However, the head of the *Orbicella* pounder has no utilitarian purpose beyond that which could be met with a plain knob. In use, the body alone is gripped, and when not in use the pounder is suspended by a loop around the neck. It seems probable that local convention required the presence of a bifurcated head on a pounder, and because of the weakness and structure of the coral material used, this could be made only by inclining the lugs. (Compare 48, p. 252.) However, the attempt to produce a strong form was only partially successful; more than half the coral pounders seen in Tubuai, Rurutu, and Rimatara had lost one of the lugs.

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Thus it might seem that while the form of the sides of the coral pounders suggest the influence of the material used, the strong convexity of the base and the upward divergence of the lugs affirm it. In all these features the *Orbicella* pounders differ markedly from those of ancient form made of stone in the neighboring islands. They suggest that the *Orbicella* type of pounder was an innovation which on account of the ease of manufacture had ousted other forms and other material.

A Tubuai coral pounder of unique form was collected by Seale in 1902, and said to be in use at that time. The specimen (fig. 39, *c*) was newly made, and had not been used. It is finer celled than the *Orbicella* pounders and has a roughly square head. The only pounder of similar workmanship seen by Aitken in Tubuai was one made by a native for sale only, and which was not at all characteristic of the Austral Islands forms. Though this pounder was probably not made for use, it has an interest in that the convexity of the body in vertical outline and the flatness of the base are features of a type which I think was ancient in Tubuai.

In addition to the pounders made of coral Seale collected a pounder of stone (fig. 39, *b*). The material is vesicular basalt crystalized with olivine and augite to a degree of coarseness almost unique in Polynesian poi pounders. Seale noted that it "probably belonged to the ancient race of the island, as the present people do not make pounders of hard stone." Its form follows the general pattern of the pounders now in use. It has seen service, but has not suffered excessive wear. Aitken made many enquiries for pounders made of stone, but was unable to duplicate the specimen collected by Seale or to find any others except those illustrated in figures 40, *a* and 40, *b*.

As the pounder appears to have been metal cut, and is so different in form or kind of stone from the stone pounders of the adjacent Society, Cook, and Austral islands, and so similar in form to the pounders made of *Orbicella* coral, I am inclined to regard it as more or less contemporary with the coral form. Possibly an attempt was made to substitute stone for the less durable coral.

Two pounders from Tubuai, because of their size, may be regarded as medicine pounders. One of them (fig. 40, *a*) undoubtedly of local origin, is a seminatural stone of very fine grain, and has seen much use. It is of interest on account of the approximate flatness of the base and of the body in outline, in these respects resembling the stone pounders from the other Austral Islands and from Cook Islands, but distinctly unlike the coral form. I believe that it approximates an older form of poi pounder in Tubuai. The other medicine pounder is undoubtedly a small pounder or muller originating in the Society Islands.

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I cannot avoid the impression that the *Orbicella* type of pounder, together with the four-legged wooden *papahia,* have replaced other forms as well as materials, and I venture the opinion that the ancient pounder was made of stone and used on a stone platter.

On Raivavae, the island nearest to Tubuai, Aitken and I observed the *Orbicella* pounder in use on the four-legged *papahia,* and independently noted that it was in process of replacing older forms in stone. Such a pounder, shown in figure 40, *c,* was formerly used on a stone slab about 15 inches wide by 20 inches long, and 3 inches thick, but now on a broad,

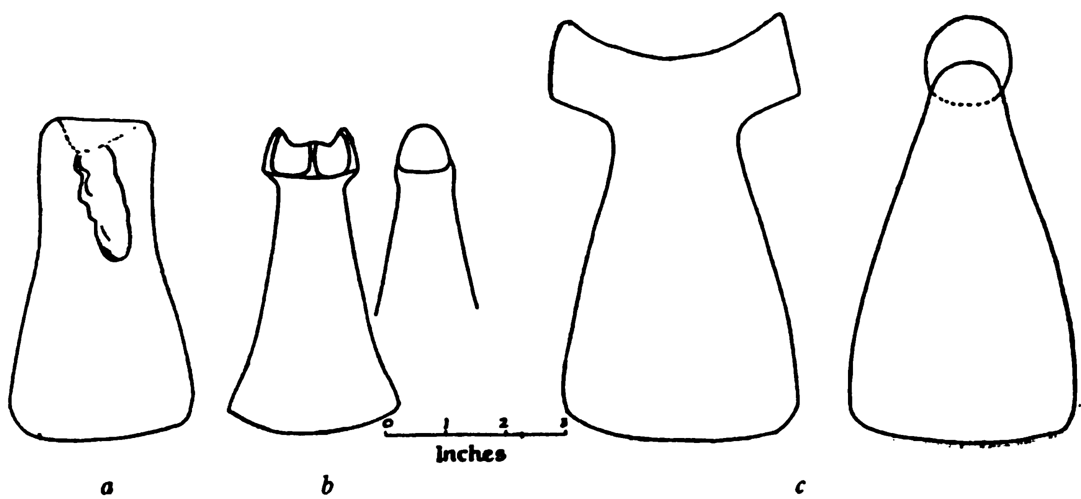

FIGURE 40.—*a,* Tubuai pounder, vertical section of seminatural stone much used as pounder, head broken, horizontal sections of neck and base subcircular, weight 2 pounds, 5 ounces (No. B. 4639); *b,* front and side views of well made pounder, horizontal section of base subcircular, rare form in Tubuai, undoubtedly an importation from Tahiti, weight 1¼ pounds (No. B. 4638); *c,* front and side views of pounder from Raivavae (No. B. 4678).

slightly concave wooden platter. The convex sides and somewhat flat base of the pounder differing so strongly from the *Orbicella* type might well imply that it was used in a different way: both hands grasping the body of the pounder and the thumbs extending over its head. It was probably used more for rubbing than pounding, like the food rubbing stones from Kauai (44). On the stone platter, vigorous pounding would soon shatter such lugs as are shown in figure 40, *c*.

In Rapa, pounders somewhat similar to the Raivavaen pounders were used, but stone was used for platters in ancient days. The four-legged wooden stand was introduced by the native missionaries from the Society Islands, and after some little vogue, was discarded for the ancient form of stone. In Rurutu, I was shown a slightly hollowed slab of stone, stated in legend to have been used for poi pounding, and was told of an ancient pounder made

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of stone. The *Orbicella* pounder now universal in Rurutu would soon be crushed if used on stone. On Rimatara I collected the Ravaivai type of stone pounder. In both these islands the *Orbicella* type alone is found in use on the four-legged *papahia,* and in Rimatara, in addition, on the broad and shallow woole nplatter as found in Ravavai.

In the Cook Islands, as noted by Buck (48, pp. 50, 246, 248), the Ravaivai form is found in Mangaia; in Aitutaki, it has been replaced in modern times by wooden pounders of pestle type; in Rarotonga, forms approximating the Ravaivai type formerly existed, but at present the *Orbicella* type prevails, and is used on the four-legged *papahia.*

Thus there is evidence of the former distribution of a stone pounder, approximating the Ravaivai type, through the Cook and Austral islands. It survives in Mangaia and in part in Ravaivai. In Aitutaki it has given way to wooden pounders. Where found, the ancient type of *papahia* is of stone. The inference is that the presence of the stone pounder type in an island implies the use of the stone platter, especially where the quality of the stone in the pounder is suitable. In Mangaia the pounders are made of stalactitic material which has but slight resistance.

Today the *Orbicella* pounder associated with the four-legged *papahia* is either general or dominant in all the islands where the stone forms had been abandoned, as indicated or inferred, with the exception of Aitutaki. Where the four-legged *papahia* is present, there also is the *Orbicella* pounder; except in Rapa, where the *Orbicella* coral probably did not grow. It seems a fair conclusion that the coral pounder and four-legged stand have displaced throughout the island groups equivalent implements made of stone, as is being done in Ravaivai today.

This conclusion applies to Tubuai, concerning which there is other evidence. The traditions of Tubuai and Ravaivai confirm each other in accounts of a migration from Raivavae to Tubuai about three centuries ago. Obviously the Ravaivai pounder and *papahia* of stone should have been present on Tubuai.

Aitken and I were also under the impression that *Orbicella* pounders are a comparatively recent development, and that their distribution is due to native missionary influence or to trade. It is remarkable that wherever found, they are about the same size and shape. They suggest a trade article, but as a pounder of "porous coral" collected by Ellis (20, p. 191) from Rurutu about 1820 may be of the *Orbicella* type, it is possible that the type was a development in one island and thence distributed. If so, the island was probably Rurutu, where the *Orbicella* pounder is more consistently represented than elsewhere. So far the pounder has not been reported from the Society Islands.

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CONCLUSIONS

The material culture of the modern Tubuai people is characterized by the taro, coconut, manioc, and banana, rather than by other vegetable foods; by fish, rather than by animal food; by the cooking of food in the umu; by the *pareu* as garment for both sexes, supplemented but not entirely supplanted by modern foreign clothing; by dwellings primitive Polynesian in material, although modern in design; by the preference of spear-fishing to other fishing methods; by the outrigger canoe, propelled by paddle or sail, but not poled; by weaving in coconut leaf (baskets and thatching material) and in lauhala (mats, hats, and baskets). These features enumerated combine to stamp the material culture of modern Tubuai as most closely related to that of modern Tahiti and to that of modern Raivavae.

The mythology of Tubuai, now almost forgotten, is distinctly Polynesian, containing elements found throughout the Austral Islands and also in New Zealand, Hawaii, and Tahiti. From certain of the more local tales it is evident that Tubuai of former days was in frequent communication with Raivavae, and to a lesser extent with Rurutu, and was at least occasionally in communication with islands to the north and east.

The social organization of the present Tubuai people reflects somewhat the social organization of former days. There were evidently definitely recognized districts, each occupied by a leading man or chief, his family, relatives, and dependent followers. There was jealousy and almost constant warfare among these districts, even though their border lines were weakened by more or less frequent intermarriages. The government was much affected by outside influence. Powerful leaders from other islands invaded Tubuai, and conquered or absorbed the families in the various districts. All evidence points to Raivavae in particular as the source of such invasions.

The modern Tubuai language is almost entirely the Tahitian dialect of today, due partly to the constant intercourse in modern times with the people of Tahiti, but more especially to the fact that the only printed book in the hands of the Tubuai people is the Tahitian translation of the Bible. Only a few words are now remembered that antedate the beginning of missionary influence; these words indicate that the former Tubuai dialect approached more closely the old Polynesian language.

Archaeological remains indicate former religious and ceremonial life and practises somewhat similar to those indicated by archaeological remains in Rurutu and Raivavae, but differing from those of Tahiti.

The present villages, judging from meager surface indications backed by evidence from other lines of investigation, are upon sites of older villages that have presumably been continuously occupied. In former times, how-

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ever, there were other villages now forgotten, and the population of the island was considerably greater.

From local records, it is evident that the influence of Raivavae upon Tubuai has been very great; there has been frequent journeying from Raivavae to Tubuai, with inevitable introduction of Raivavae culture and blood.

The records of early voyagers and missionaries unfortunately contribute little to the knowledge of Tubuai beyond a few scattering notes on material culture. One item of information from these sources concerns the epidemics of disease that have swept the island since its discovery. The result of the reduction in population so caused has undoubtedly been to increase the immigration, and consequently to diversify both the culture and the physical type of the modern Tubuai people.

The utmost care is necessary in deciding which elements of the modern culture are truly characteristic of the ancient Tubuai people, and which have been introduced. I am strongly inclined to believe that prior to 1777, when the island was first visited by Europeans, there was frequent communication between Tubuai and Raivavae; that there were closer relations between the Austral Islands and the Cook Islands than between the Austral Islands and the Society Islands, and that there may have been early relations with the Tuamotu group. I believe that a very large part of the modern culture, especially those elements that resemble most closely corresponding elements in the modern culture of Tahiti, are due to the standardization of language, religion, material and nonmaterial culture, and physical type that followed naturally the invasion of the Christian missionaries.

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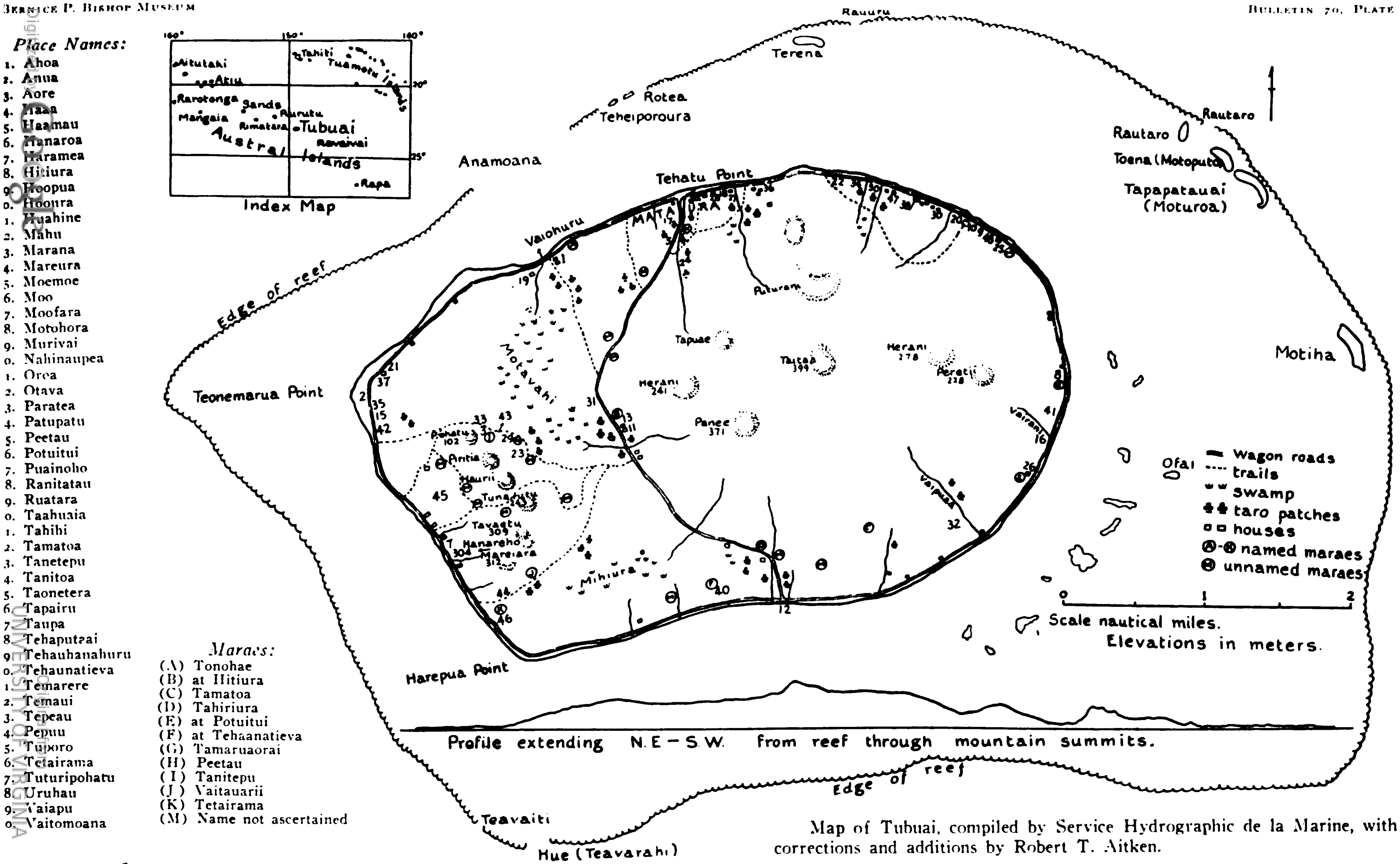
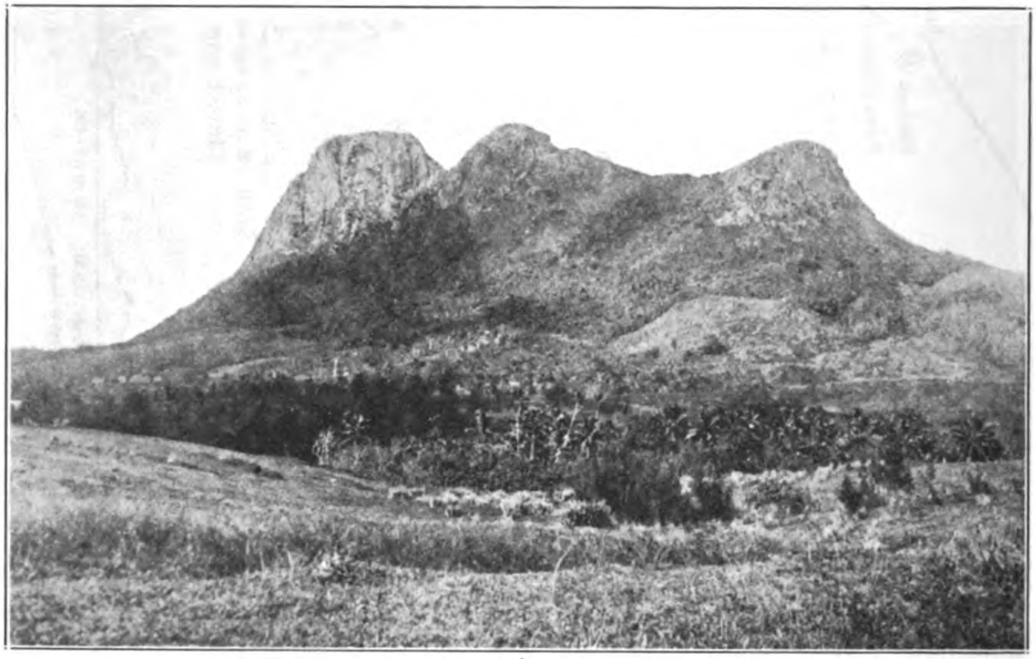


Map of Tubuai, compiled by Service Hydrographic de la Marine, with corrections and additions by Robert T. Aitken.



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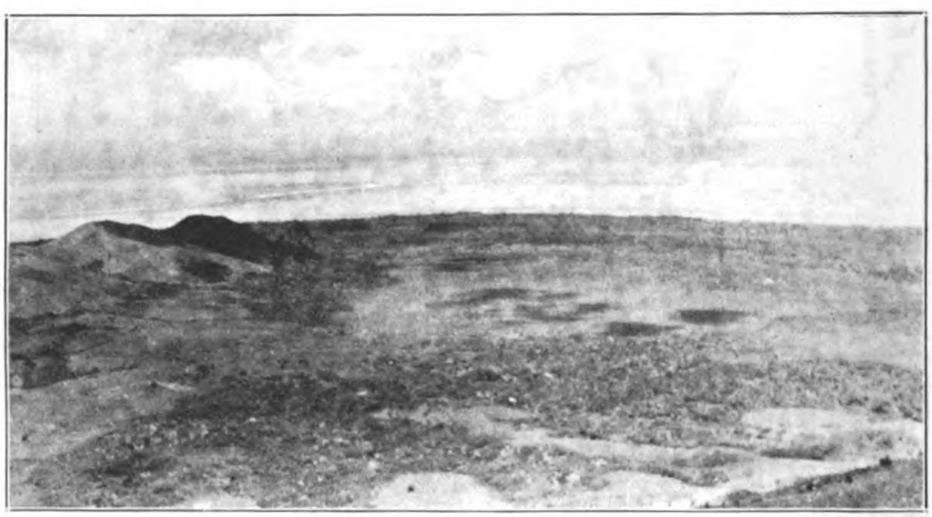

B

LANDSCAPES OF TUBUAI: *A*, GROUP OF PEAKS AT THE WESTERN END OF THE ISLAND; *B*, VIEW LOOKING WEST FROM MOUNT TAITAA, ACROSS A LARGE SWAMPY AREA; BARRIER REEF IN DISTANT BACKGROUND.

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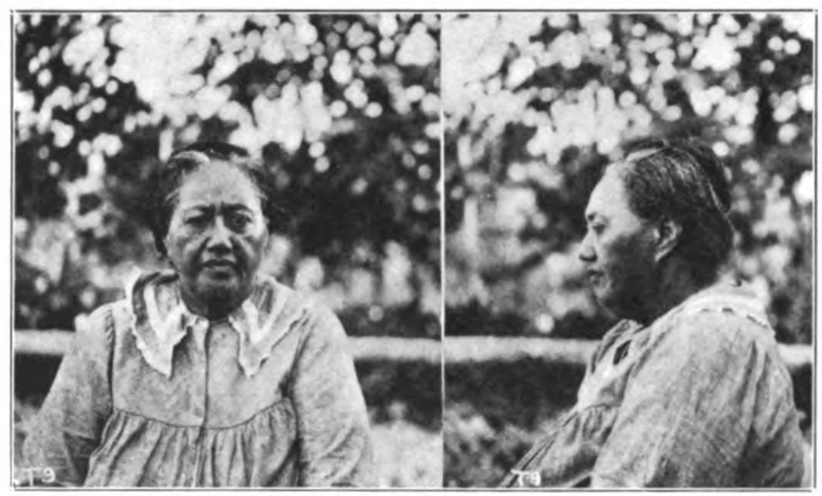

D

NATIVES OF TUBUAI: *A*, MAN TWENTY-TWO YEARS OF AGE; *B*, MAN FORTY-FIVE YEARS OF AGE; *C*, WOMAN ABOUT TWENTY YEARS OF AGE; *D*, WOMAN ABOUT FIFTY YEARS OF AGE.

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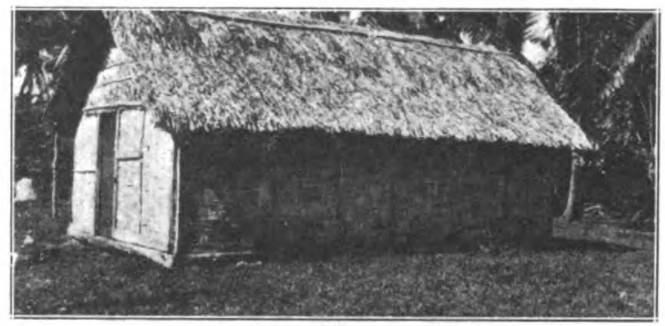

D

TUBUAI HOUSES: *A*, WITH LAUHALA ROOF, NIAU, AND UPRIGHT BAMBOO WALLS; *B*, WITH NIAU ROOF, HORIZONTAL SLAB WALLS; *C*, WITH LAUHALA ROOF AND PLASTER WALLS, COOK HOUSE IN THE BACKGROUND, WITH NIAU ROOF AND UPRIGHT POLES FOR WALLS; *D*, WITH LAUHALA ROOF AND WOVEN BAMBOO WALLS.

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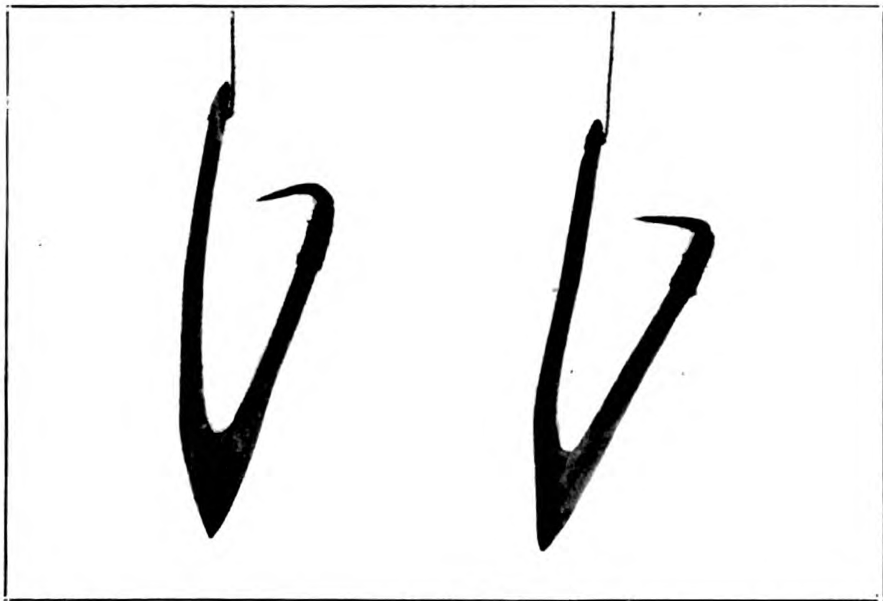

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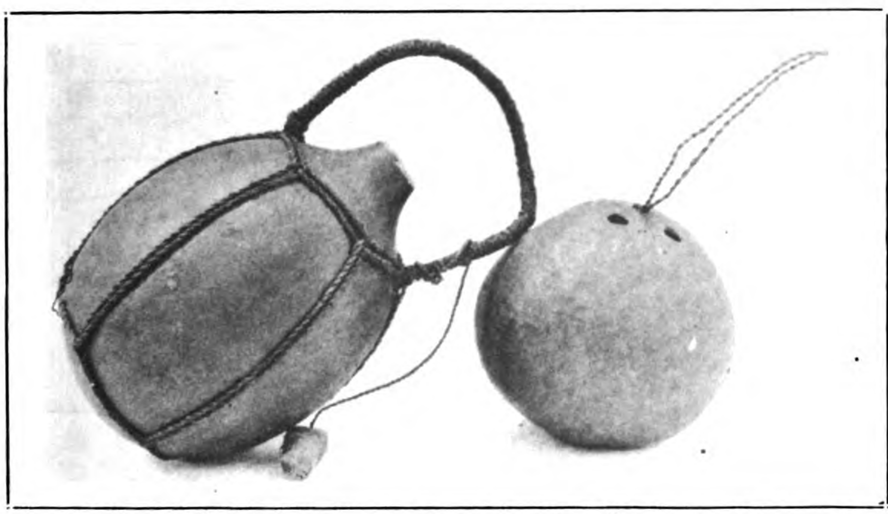

B *C*

FISHHOOKS AND WATER BOTTLES: *A*, WOODEN FISHHOOKS, USED FOR DEEP SEA FISHING, WITH LASHINGS OF BANYAN FIBER; *B*, GOURD FOR CARRYING SEA WATER, IN SLING OF NETTED SENNIT; *C*, COCONUT BOTTLE FOR FRESH WATER, WITH SENNIT CARRYING CORD.

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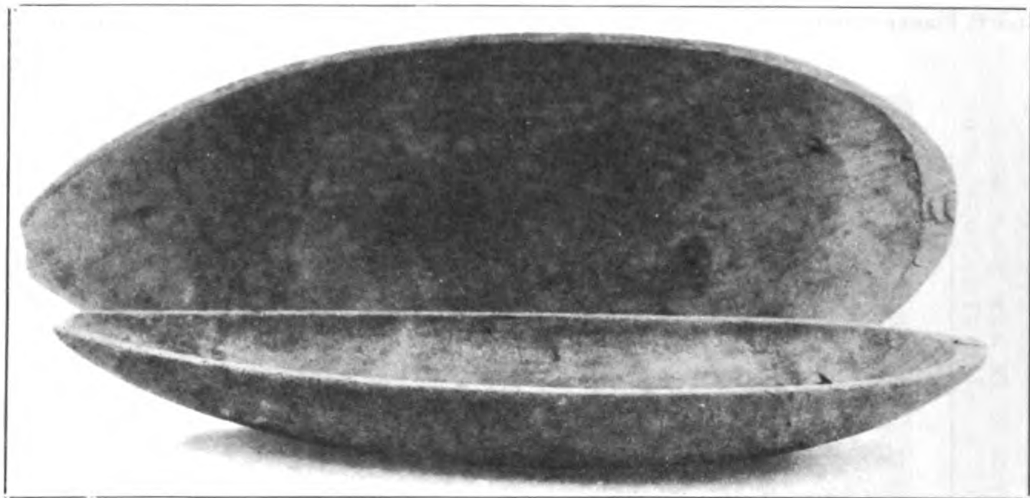

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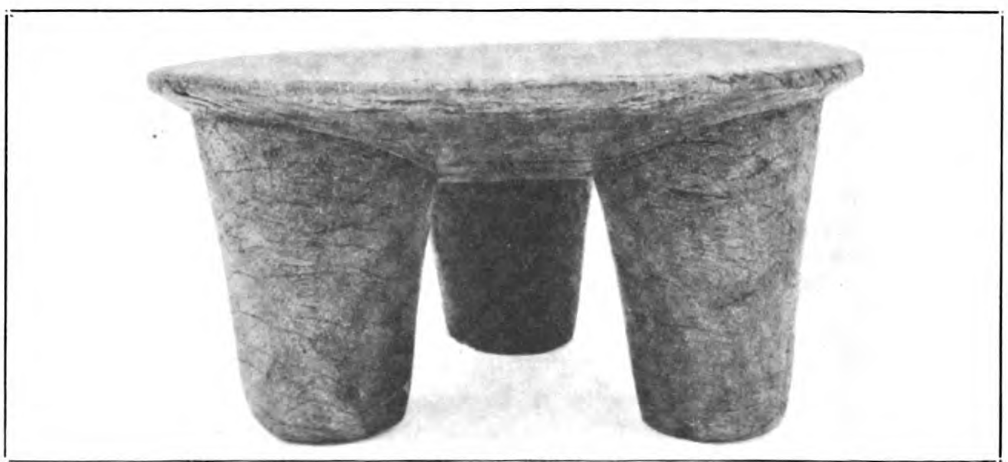

D

ANCIENT WOODWORK: *A*, UMETE (WOODEN BOWL) USED FOR GENERAL HOUSEHOLD PURPOSES; *B*, FRAGMENT OF AN IMPLEMENT SHOWING HERRINGBONE DESIGN (LENGTH 2 FEET, EXTREME WIDTH 2 INCHES); *C*, HEAD OF A SPEAR; *D*, THREE-LEGGED POI BOARD.

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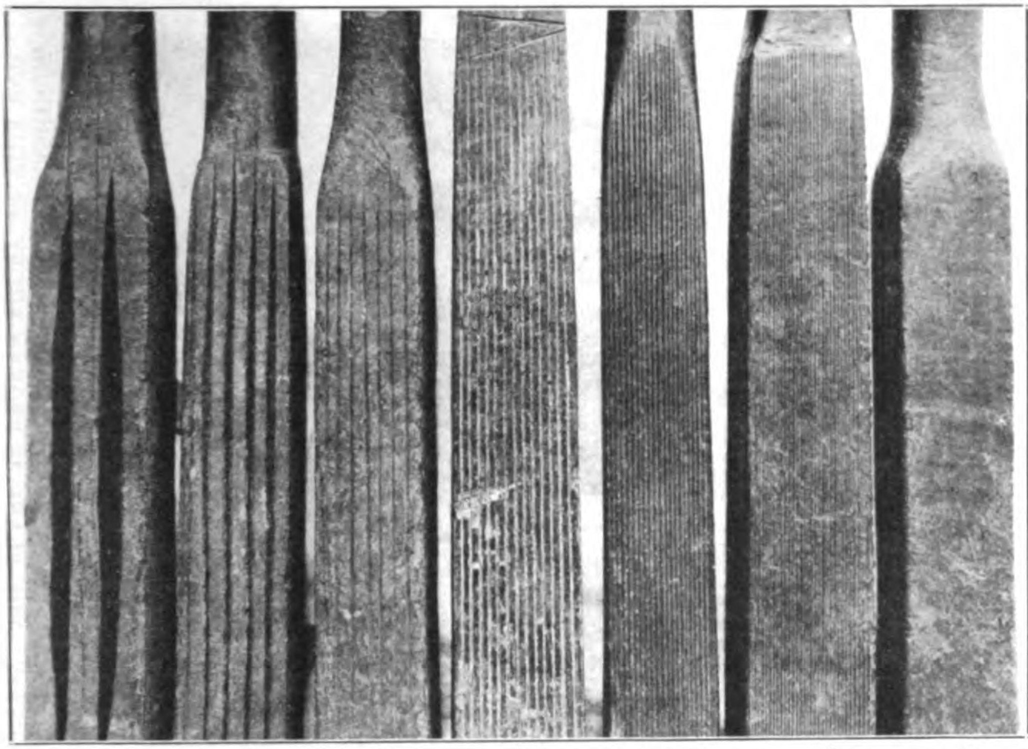

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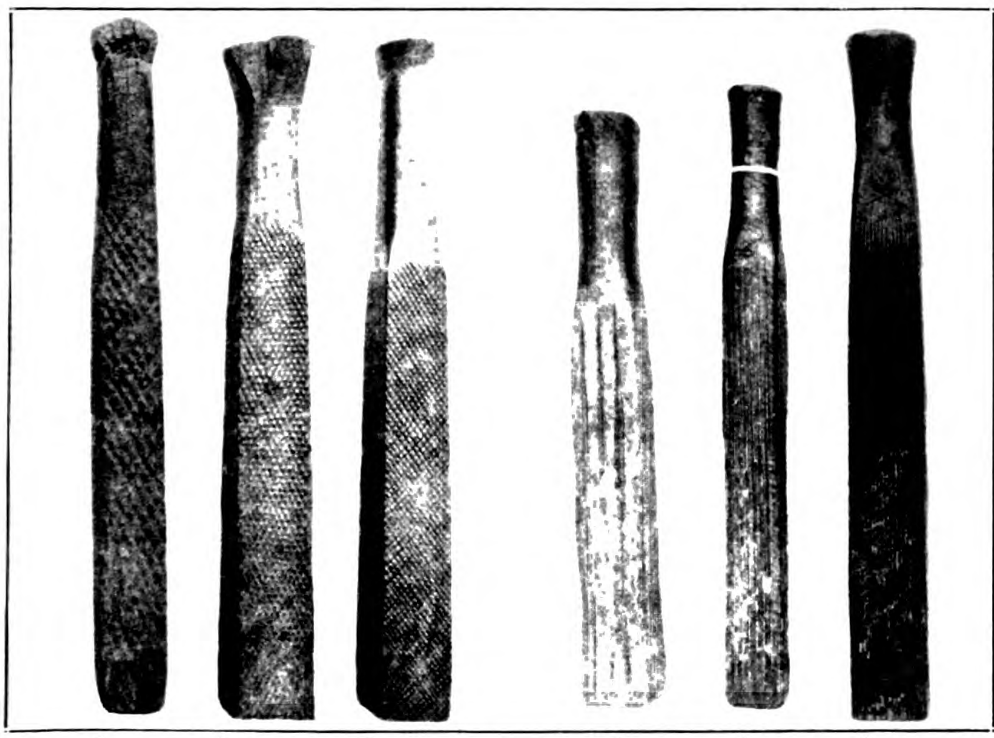

1 2 3 1 2 3

B *C*

TAPA MALLETS: *A*, SERIES SHOWING GRADATIONS IN PARALLEL GROOVINGS; *B*, SERIES SHOWING LOZENGED FACES; *C*, THREE MALLETS USED IN MAKING ONE SHEET OF TAPA (FOR MEASUREMENTS SEE P. 66).

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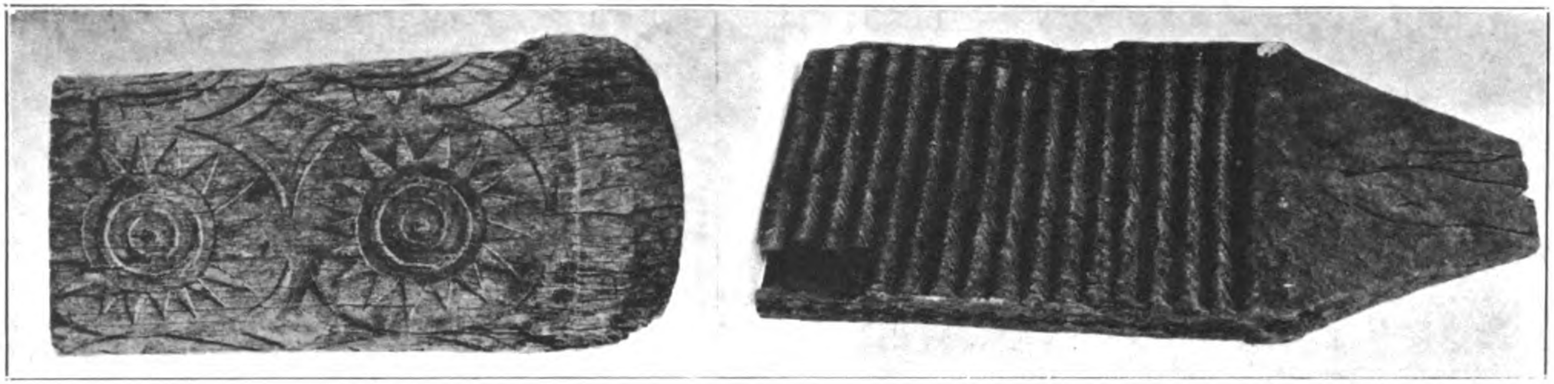

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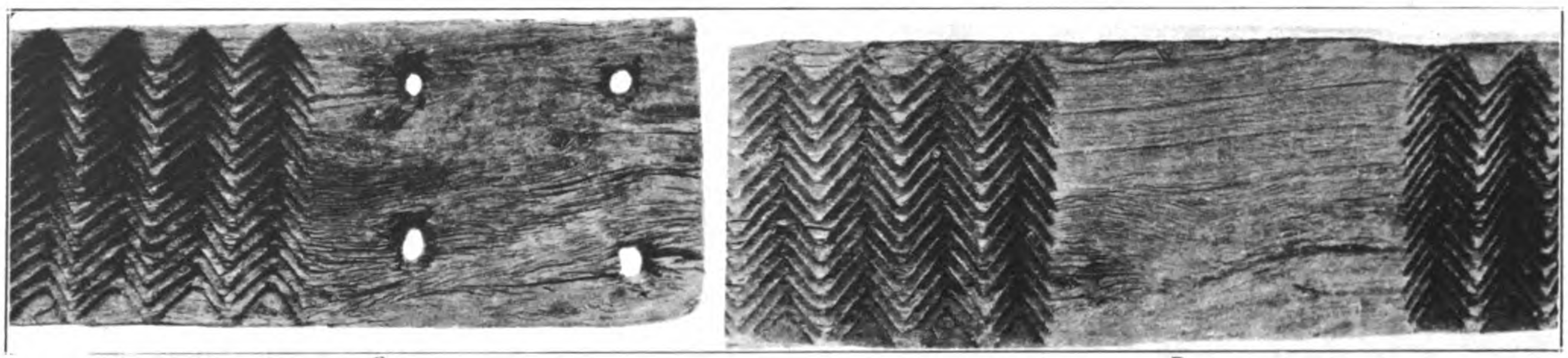

C D

ANCIENT WOODWORK: *A*, SECTION OF OLD HOUSE POST FROM MATAURA, TUBUAI, WITH CONVENTIONAL DESIGN; *B*, SECTION OF PLANKING, CARVED WITH HERRINGBONE DESIGN; *C*, END OF CARVED PLANK SHOWING HOLES CUT FOR LASHINGS; *D*, OPPOSITE END OF SAME PLANK, SHOWING UNORNAMENTED SECTION. THE PLANK IS BROKEN SHORT AT THIS END.

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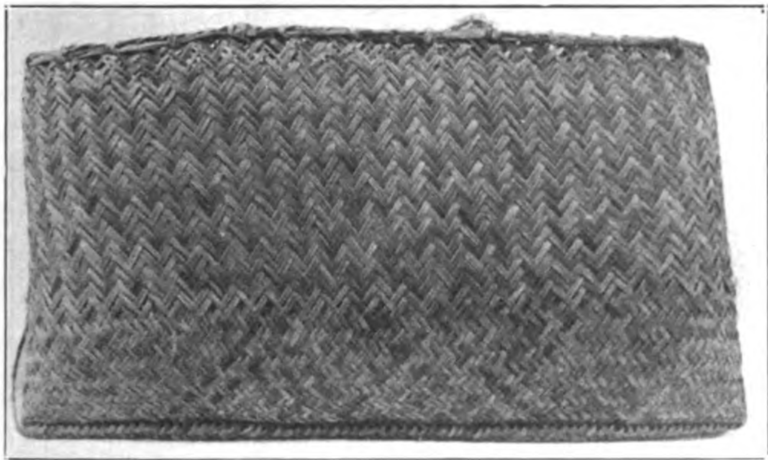

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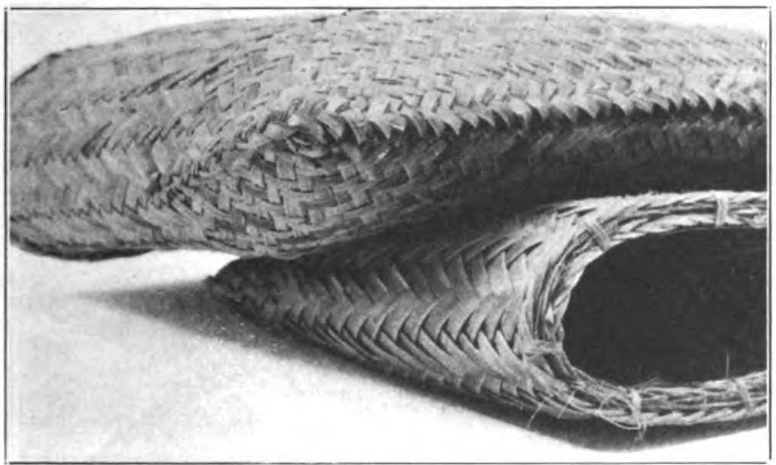

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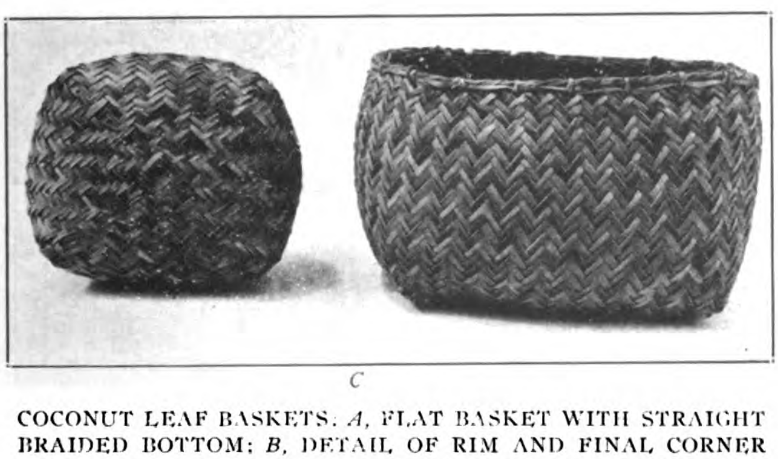

C

COCONUT LEAF BASKETS: *A*, FLAT BASKET WITH STRAIGHT BRAIDED BOTTOM; *B*, DETAIL OF RIM AND FINAL CORNER OF SAME BASKET; *C*, BASKET WITH SQUARE BASE, SIDE AND END VIEWS.

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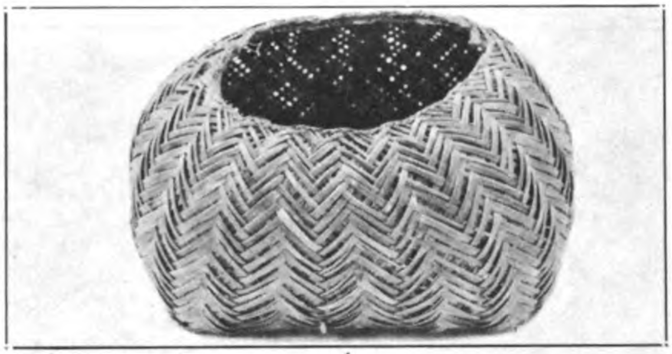

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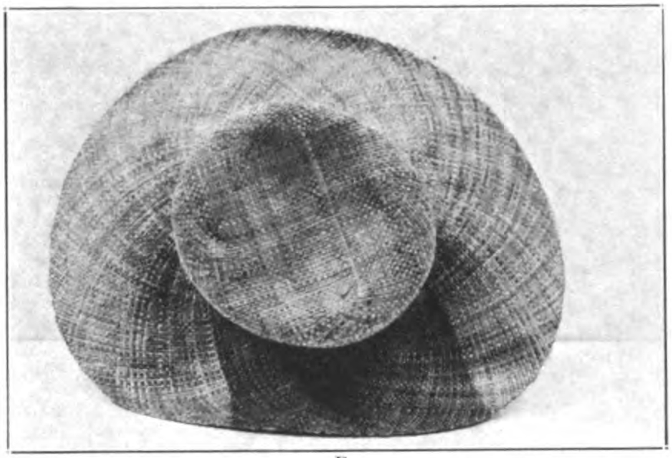

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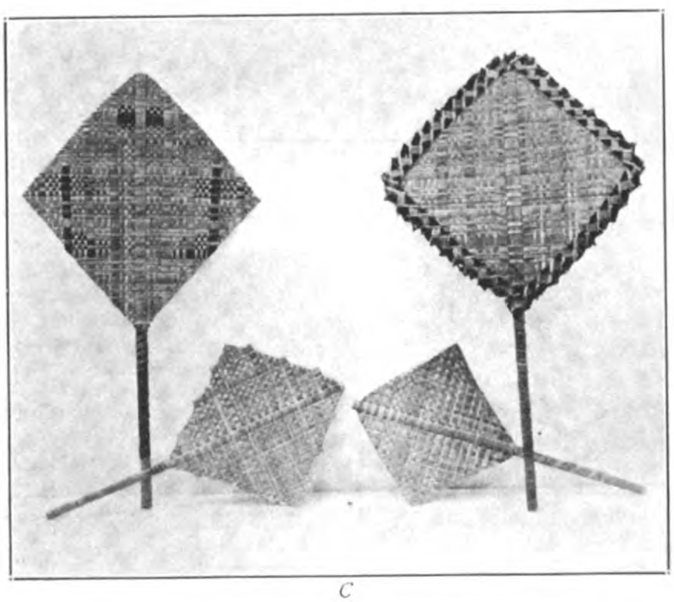

C

WEAVING: *A*, BASKET WITH SQUARE BASE OF THE SO-CALLED TUAMOTU WEAVE, WITH BASE SIMILAR TO THAT SHOWN IN PLATE IX, *C*; *B*, LAUHALA (PANDANUS) HAT, SHOWING THE FOUR CORNERS OF THE INITIAL SECTION OF THE CROWN; *C*, LAUHALA FANS OF DIFFERENT WEAVES, TWO ARE DECORATED WITH STRIPS OF THE OUTER SKIN OF FEI TREES.

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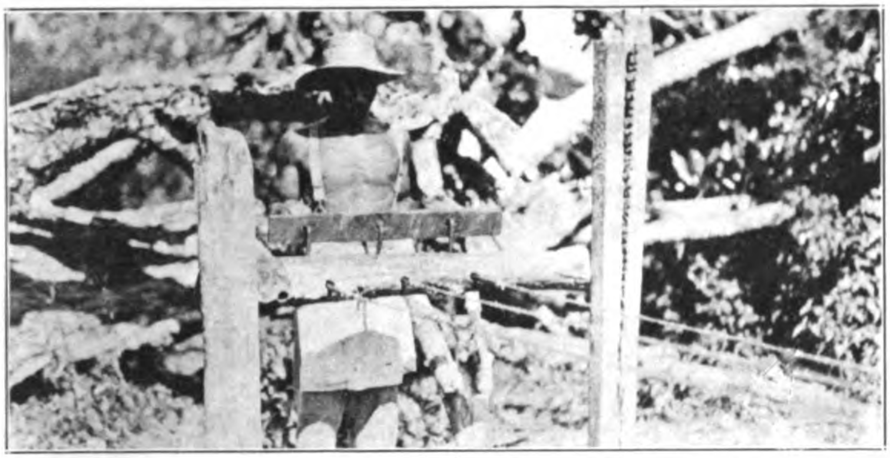

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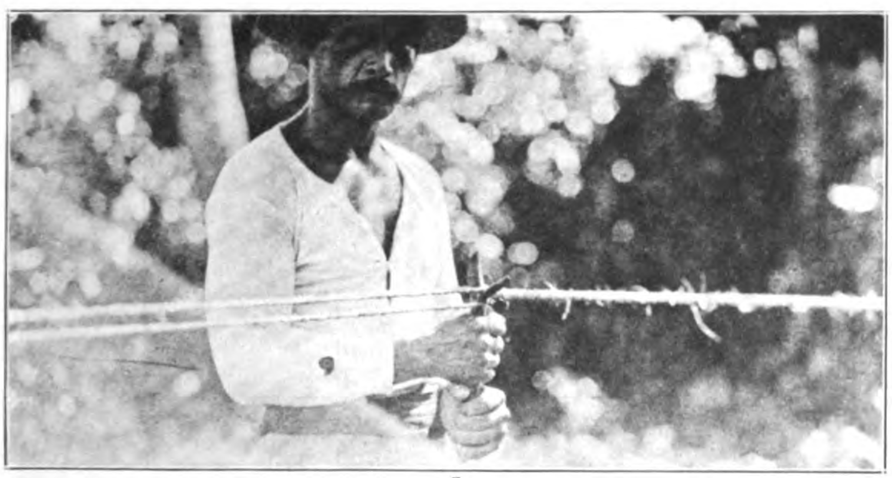

C

MAKING ROPE OF HAU FIBER: *A*, MATAPO, A BLIND BOY, TWISTING THREE STRANDS SIMULTANEOUSLY; *B*, THE DRAG, ON WHICH IS MOUNTED THE SINGLE CRANK FOR TWISTING THREE STRANDS INTO ONE; *C*, TEOTO MAINTAINING THE PROPER DEGREE OF TENSION IN STRANDS AND ROPE AS THE TWISTING CONTINUES.

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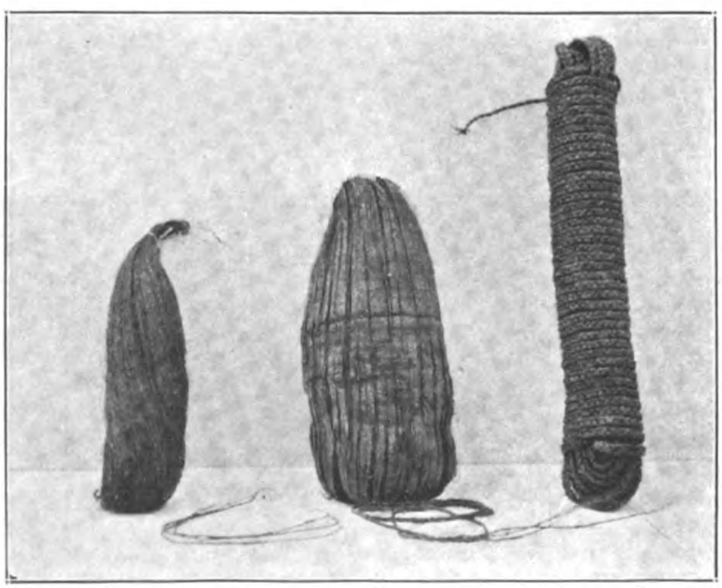
B



1 2 3

C

MAKING SENNIT OF COCONUT HUSK FIBERS: *A*, ROLLING SEPARATE FIBERS INTO A STRAND; *B*, BRAIDING THREE STRANDS TOGETHER INTO THE FINISHED CORD; *C*, STAGES IN SENNIT MAKING: 1, THE HANK OF FIBERS; 2, THE BEATEN HUSK; 3, A FINISHED HANK OF CORD READY FOR USE OR SALE.

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MOOTUA VAHINE MAKING TAPA.

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THE GEOLOGY OF KAUAI AND NIIHAU

BY

NORMAN E. A. HINDS

BERNICE P. BISHOP MUSEUM

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ILLUSTRATIONS

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The Geology of Kauai and Niihau

By

Norman E. A. Hinds

INTRODUCTION

SCOPE AND PURPOSE

Geological investigations in Hawaii have been very largely centered on the volcanic sink at Kilauea. The opportunities for the study of volcanic mechanism in this great, natural laboratory have proved more attractive to most field workers than the rather prosaic tack of unravelling the history of the extinct eruptive centers of this group. Before the beginning of the present decade, relatively little intensive geological work had been done in other parts of the archipelago; many reconnaissance observations had been published, but no area had been thoroughly investigated. The most valuable general reports are those of Dana (19)[1], who visited Hawaii, Oahu, and Kauai in 1840 and Hawaii, Maui, and Oahu in 1887; and of Dutton (23), who made a brief reconnaissance of parts of Hawaii, Maui, Oahu, and Kauai in 1882. Though these investigators spent only brief periods in the field, their recorded observations will serve as the basis for all later geologic and morphologic studies in Hawaii and in similar volcanic regions. Their reports discuss the nature of volcanic action, and describe the general characters of the lavas, but petrographic descriptions are not included. In a later publication, Dana (21) summarized his view of the geology of the Hawaiian islands and gave the microscopic characters of a few lavas from the islands of Hawaii, Maui, and Oahu. Two papers by Hitchcock (38) are largely confined to a description of the more recently developed geologic and morphologic features of Oahu, especially in the vicinity of Honolulu. A work by Bryan (5) contains a chapter on the geology of the leeward and windward Hawaiian islands.

Though Hawaii is the best known and the most easily accessible volcanic group in the Pacific, and information regarding the various phases of its geology is needed as a basis for studies on other volcanic islands, no thoroughgoing petrographic descriptions of systematic rock collections from any of its principal eruptive centers have been made. The recent contributions by Washington (58) to the petrology of the archipelago are of great value, but these should be supplemented by miscroscopic examination and chemical analyses

[1] The numbers in parentheses refer to Bibliography on pages 102-103.

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of more extensive suites which represent thorough samplings of the eruptive and irruptive rocks of the various domes. Only by such means can the geologist be sure that important rock types have not been overlooked and that discussions of the genesis of the lavas are based upon a complete knowledge of the varieties composing the various eruptive centers. As the area of the archipelago is little more than 6,000 square miles, intensive field studies carried on for a few years would yield the facts which are most desired at the present time. Fortunately the Bernice P. Bishop Museum in Honolulu is sponsoring a number of such investigations. Under its auspices, Wentworth (60, 61) has published bulletins on the geology of Lanai and of Oahu; Palmer (48) has examined a number of leeward islands; and Stone (57) has described the geology of Kilauea.

Some years ago, Professor R. A. Daly urged me to take part in a systematic study of Hawaiian geology by making a detailed examination of one or more of the islands. This plan was later made possible through a liberal grant by the Committee on Sheldon Fellowships of Harvard University. The island of Kauai was selected because it has been extensively dissected and therefore seemed to offer the best opportunity for deciphering the subsurface volcanic structures, for the collection of a representative suite of igneous and sedimentary rocks, and for observation regarding the geomorphic development of a lava dome which long since has become extinct. Also, the United States Geological Survey, in 1911, had published an excellent map of the island, thus supplying a topographic base for the geologic studies. In 1921 I spent six months in the field and in 1922 was able to continue the investigation during the three months of the summer as a Bishop Museum Fellow in Yale University. The greater part of the two seasons was spent on Kauai. In addition, I made a reconnaissance survey of Niihau, and brief comparative studies on Oahu, Maui, and Hawaii.

The chief problems studied in the field were:

1. The subsurface volcanic structures and the nature of the igneous mechanism.

2. The lavas and pyroclastic deposits erupted long after the close of the principal eruptive period and after most of the existing topographic features had been developed.

3. The topography as affected by age, types of erosion, and faulting. Because little attention has heretofore been paid to the development of the relief of extinct or quiescent lava domes, I considered this one of the major field problems.

4. The sedimentary rocks and the conditions of sedimentation.

Extensive suites of the igneous and sedimentary rocks, the weathered

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lavas and various types of soils, and such fossils as are present were collected for laboratory study.

The present report discusses the morphology and general geology of Kauai and, in less detail, of Niihau. In papers to be published later I propose to deal with the petrography of the igneous rocks, the volcanological problems, the nature of rock weathering, the formation of soils in Hawaii, and also to give a more complete description of the sediments.

ACKNOWLEDGMENTS

The field studies embodied in this report were undertaken at the suggestion of Professor R. A. Daly, and under his inspiration and unfailing guidance, the assembling of results has been carried to completion. Throughout the course of the work, I have been aided in many ways by others, and to them I offer hearty thanks. Professors J. E. Wolff, W. M. Davis, and R. de C. Ward have given valuable counsel on many of the problems. Professor H. E. Gregory, Director of the Bernice P. Bishop Museum, placed the facilities of that institution at my disposal and assisted in securing equipment for the field work. Dr. H. S. Washington is analyzing a number of the igneous rocks in connection with his studies of Hawaiian petrology. Professor Junius Henderson of the University of Colorado has identified the fossils collected on Kauai and Niihau. Mr. A. O. Burkland, in charge of the Hawaiian branch of the United States Geological Survey, rendered valuable assistance in many ways. Climatological data were furnished by Mr. L. H. Daingerfield, formerly in charge of the Hawaiian Section of the United States Weather Bureau.

While in the field, I found the people of Hawaii extremely cordial and ready to cooperate in carrying on the research whenever possible. I should have been unable to examine a very considerable part of Kauai had it not been for guides, horses, and lodging places furnished by the plantation authorities and by others. Special acknowledgment must be accorded to the late J. M. Lydgate, who constantly advised and guided me during my work on Kauai. Through the courtesy of Mr. Aubrey Robinson and family, a visit to Niihau was made possible, and also an examination of the Kaholuamanu region on Kauai. Thanks are also due Mrs. J. M. Lydgate, Mrs. D. R. Isenberg, Mr. F. J. Dollinger, Mr. R. D. Moler, Mr. W. H. Rice, Judge L. A. Dickey, Mr. L. D. Larsen, Mr. F. A. Alexander, Mr. B. D. Baldwin, Mr. H. P. Faye, and Mr. W. J. Hardy of Kauai; to Mr. J. Waterhouse, the late Mr. Alonzo Gartley, and Professor H. S. Palmer of Oahu; to Mr. H. A. Baldwin, Mr. B. Williams, Dr. G. S. Aikens, Mr. R. Penhallow, and Mr. L. Smith of Maui; and to Dr. T. A. Jagger, Jr., and Mr. R. H. Finch. To Mr. E. P. Lydgate, my assistant in the field during two seasons, thanks are due for loyal and capable service. I am indebted to Mr. R. D. Russell

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of the University of California for assistance and suggestions in the preparation of the manuscript.

PREVIOUS GEOLOGICAL INVESTIGATIONS

Kauai and Niihau lie off the main line of travel in Hawaii, and hence have not been visited by many geologists. Niihau is privately owned, and is closed to the public.

In 1840, Dana spent four days on Kauai and visited a number of localities. His report (21) gives the most complete and accurate account of the general geologic and morphologic features of the island; though, in the light of more extended investigations, certain of his conclusions must be revised. Dana (18) summarized his early sketch of the geology of Kauai in a volume published after his second visit to Hawaii in 1887. Dutton (23) spent a short time on Kauai in 1882, but makes only casual references to the island. Cross (7) in 1902 and Powers (52) in 1915 collected igneous rocks from Kauai, and their reports mention certain of the geological features. Two papers by Powers (52, 53) contain brief notes on the geology of Niihau. Bryan (5) and Hitchcock (40) describe the general characters of the geology of both Kauai and Niihau.

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GEOGRAPHY OF KAUAI

GENERAL FEATURES

The Hawaiian Archipelago, consisting of two distinct sections, the windward and the leeward, extends for more than 1,900 miles along the northern margin of the tropical climatic belt. The windward islands lie between latitudes 18° 54′ and 22° 15′ north; the leeward islands between 23° and 28° 15′ north. The windward section is composed of five large and three small islands extending from Kauai and Niihau southeastward to Hawaii—a distance of about 300 miles (fig. 1). Excepting Kahoolawe, the windward islands are inhabited.

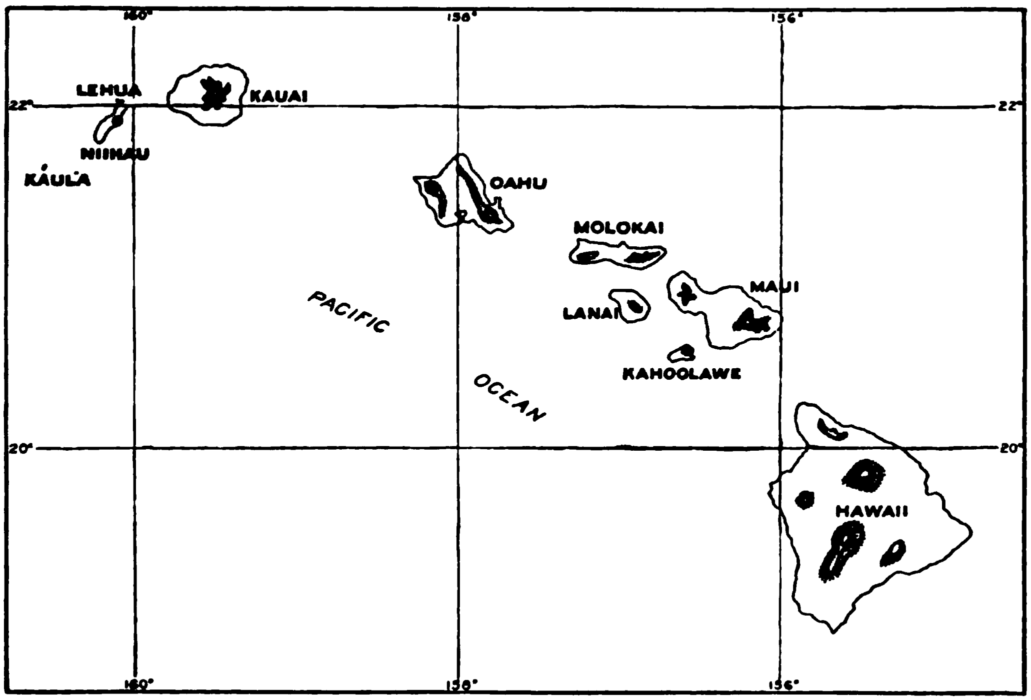

FIGURE 1.—The windward section of the Hawaiian Archipelago. From U. S. Coast and Geodetic Survey, Chart No. 4102.

West of Kauai and Oahu the archipelago is continued for more than 1,300 miles by 13 islets which have a total area of about 6 square miles. At the eastern end of this leeward group are four volcanic stacks with bordering reefs; the highest stack rises 895 feet above sea level. To the westward are atolls and calcareous sand islands with which no remnants of volcanic rocks are associated. In detail, the leeward group is composed of 6 bank atolls, 4 banks with cliffed central islands or stacks of lava partially surrounded by reefs, 5 banks without reefs or central islands, and 2 intermediate forms. The banks are 10 to 30 miles in diameter; the maximum depth of water over

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their surfaces in few places exceeds 30 or 40 fathoms. On Midway Island is an important American cable station; otherwise the leeward islands are uninhabited. Eight islands of the group have been set aside as a Federal Bird Reservation.

A deep channel, 68 miles in width, lies between Kauai and Oahu, and Nawiliwili, the nearest landing on Kauai is 90 miles from Honolulu. Semidesert Niihau is a comparatively small island about 20 miles southwest of Kauai. On unusually clear days, the summits of the western mountains of Oahu are dimly visible from the eastern shore of Kauai, and, from the western side of Kauai, the cliffed dome remnant of Niihau usually can be seen.

Kauai is a deeply eroded, subcircular island, fourth in size in the Hawaiian Archipelago. Its area is 547 square miles. The maximum east-west diameter of Kauai is 32 miles; the maximum north-south diameter, 22 miles. The highest elevations, located near the center of the island, are about 5,000 feet. Adjoining Kauai is the island of Niihau with its associated tuff cones, Lehua and Kaula. (See p. 96.)

POPULATION

The chief elements in the population of Kauai, which was 29,247 according to the census of 1920, in order of numbers are Japanese, Chinese, Hawaiians, Portuguese, and Americans. As elsewhere in Hawaii, the pure native element is decreasing and that of mixed blood is increasing by intermarriage of the full-blooded Hawaiians with the whites and the Chinese. The number of Japanese is also being rapidly augmented because of the high birth rate among that people. Most of the population lives in small towns or plantation settlements, located on the lowlands of northern, eastern, and southern Kauai, or in scattered dwellings on the alluviated flats of the mouths of the river valleys crossing the lowlands. The chief towns are Kilauea, Kapaa, Lihue, Koloa, Hanapepe, and Waimea. Lihue, the county seat, is the principal town, though Waimea has a slightly larger population. The mountain section, because of its extreme ruggedness, inaccessibility, and in certain parts, because of its rainy climate, is almost uninhabited.

INDUSTRIES

The chief industries of Kauai are those common elsewhere in Hawaii—the cultivation of sugar cane, pineapples, and rice; fishing and cattle raising. The sugar plantations, which constitute the principal industrial enterprises, are confined to the lowlands except on the southern side of the island where fields extend to elevations of 1,100 feet. Apparently there is no physical reason why sugar cane should not be grown at higher elevations, as valuable crops are elsewhere raised at elevations of 2,000 feet. On Kauai however, the difficulties of cultivation, irrigation, and transportation over the rugged up-

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land slopes are serious drawbacks. On the windward side, the greater amount of cloudiness and precipitation and the consequently somewhat lower average temperatures along the inner margins of the lowlands limit the elevation at which cane can be profitably grown. The crop requires long continued hot weather as well as large quantities of water. The planters find the soil and climate most favorable on the lower leeward (southern and southwestern) slopes, and there have developed the most successful plantations. On the windward lowlands, the yield of cane per acre is less; more intensive fertilization of the soil is required; replanting is necessary at frequent intervals; and every few years the fields must be allowed to lie fallow for a period of several months. Along the northern shore, where the lowlands are most heavily drenched with rain, conditions are least favorable for the growth of cane; in this section there is but one plantation as compared with six along the southern shore and three on the eastern side.

In the past, pineapples have been raised chiefly in localities where sugar cane could not be successfully grown. Since the World War, however, the acreage of cane fields has decreased and much of this land, as well as many formerly untilled areas, is now devoted to the cultivation of pineapples. The crop requires less attention and less irrigation then does sugar cane, and the demand for the canned product is growing. The pineapple industry bids fair to develop rapidly throughout Hawaii, though it will never replace the cultivation of sugar cane as the main industry. The main centers of pineapple growing on Kauai are near Lawai and in the Moloaa district. Canneries have been built at Lawai and Kapaa.

Rice culture is confined to small areas in the valley flats; the crop is not sufficient to supply the inhabitants and large quantities are imported. Some taro, from which the native food, poi, is made, is also grown in the valleys. Both taro and rice require great amounts of water, hence they can only be raised on the alluviated flats in the mouths of valleys where plenty of water is obtainable.

Fishing is actively carried on along the shores and in the adjacent deeper waters by the Japanese and Hawaiians. Several cattle ranches are located in various sections of the island, and considerable numbers of cattle and horses are raised.

Copra is produced in small quantities on eastern Kauai. Attempts to cultivate the coffee berry and sisal plant have not been successful on a commercial scale.

IRRIGATION

In spite of the heavy rainfall over most of Kauai, the sugar, rice, and taro crops require large additional quantities of water for their growth. Even before the coming of the white men, the natives constructed small

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ditch systems through their taro fields. At the present time, irrigation is practiced on a large scale, and ditch systems have been constructed in nearly all valleys between the Waimea and Wainiha rivers to carry waters from the upper reaches of the streams to the cane or rice fields on the lowlands or in the valley bottoms. The various ditch systems have been described by Martin and Pierce (45). A number of reservoirs have been built to store waters for irrigation and power; most of these are on the southern lowland in the Koloa and Hanapepe districts. The reservoir of the Koloa Sugar Company has a capacity of two and a half billion gallons—the largest on the island. The McBryde Sugar Company maintains pumping plants in Hanapepe and Lawai valleys, operated by a power station in Wainiha Canyon on the northern side of the island. The wells in Hanapepe Valley are about 3 miles from the sea and are more than 100 feet deep. In this system are three principal shafts, and more than 1,000 feet of tunnel. They supply about 20,000,000 gallons of water daily to the cane fields in these valleys. The same company drilled wells nearer the sea coast, but abandoned them because the waters in a short time became saline. The pumping plant of the Koloa Sugar Company which will raise 3,000,000 gallons every 24 hours is also operated by electricity.

Many wells have been drilled at various places on the lowlands for irrigation and domestic purposes. In those sunk near to or below sea level, the water has become brackish or saline in a relatively short time, indicating an active penetration of the lavas by sea water which is retarded only when the subsurface percolation of fresh water is not impeded. These wells are useless after the original supply of fresh water is drawn off.

HARBORS AND ROADS

The principal embayments in the Kauai coast are at the mouths of the Hanalei, Anahola, Hanamaulu, Huleia, Hanapepe, and Waimea rivers. No indentations of consequence are present along the cliffed northwestern coast or in the plain of western and southwestern Kauai. The chief stopping place for interisland ships is Ahukini in Hanamaulu Bay, the only place on the island where steamers can make fast to a wharf. From ships anchored off shore, passengers and freight may be landed in small boats at Waimea, Makaweli, Eleele, Koloa, and Port Allen on the south side of the island; at Kealia and Kilauea on the east coast; and at Hanalei. Work in progress at Nawiliwili Bay is designed to provide for Kauai a harbor which will permit large ships to anchor in safety at docks easily accessible from the back country.

A good road, paved most of the way, has been constructed along the coast nearly around the island from Barking Sands to Haena. Elsewhere the roads generally are not paved, and are mainly confined to the lowlands.

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A road extends from Waimea to Kokee in the north central highlands where a number of mountain houses have been built, and roads have been built for some distance up most of the larger canyons. The dirt roads generally are in fair condition during the dry season, but frequently become impassable in the rainy months. Trails are abundant where the vegetation is scanty; in the jungle section the traveler generally must cut his way.

CLIMATE

Regional Features

The Hawaiian islands are geologic and geomorphic units lying well within the belt of the northeast trades. Over their surfaces, the winds blow with a more or less constant velocity; moderate to extreme differences of temperature from sea level to the summits of the domes prevail depending upon their elevations; and in most places there are extraordinary variations in the annual rainfall within short distances over the same mountain.

It is difficult to find anywhere greater constancy of atmospheric conditions than those prevailing over the ocean in the heart of the Trade Wind belt, where the Hawaiian Archipelago is located. The temperature varies little from summer to winter, and the general drift of the atmosphere is rarely interrupted by storms of great violence. Yet over the islands themselves "it may be said that there are almost as many climates as there are square leagues"; striking climatic contrasts are to be found in areas only a few miles apart.

According to Daingerfield (8) these local differences result from wide variations in rainfall over different sections of the islands and from the greater variability of the temperatures at the higher elevations. It is possible to quickly pass from the persistent summer of the sea coast and the lower mountain slopes to the chill climates of the highest summits, from highly arid regions to areas of frequent, heavy rains, from dominant sunshine to almost continuously cloud-draped mountain crests. The rainfall, which is the most variable of the climatic elements, is heaviest over the windward slopes; over the leeward portions of the various domes the precipitation is relatively light. The generally prevalent northeast winds are occasionally displaced for periods of a few days by southerly or southwesterly (Kona) winds which often blow with great violence and are frequently accompanied by unusually heavy rains over the leeward sections of the domes. Henry (31) considers the Kona storms to be the troughs of cyclonic depressions whose centers move eastward to the north of Hawaii. They travel slowly, and may require several days for their passage through the group. Though Kona storms are infrequent and irregular in their occurrence, they greatly affect the precipitation; the rainfall during a single one of these storms may exceed the

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annual average for a given section. Thus very striking contrasts are afforded in the records of annual precipitation at various stations during a series of years.

As pointed out by Daingerfield (8), the temperatures depend almost wholly on elevation, though they are affected

> . . . in a minor way by the slope and exposure to the wind. The range of mean monthly temperature from summer to winter in the lower levels throughout the islands is slight, ... while the drop in temperature from sea level to the highest elevations corresponds closely to what might be expected of temperature gradients in the tropics. . . . Generally speaking, the extreme highest temperatures have been recorded on the leeward, and, consequently, the drier, sunnier sides of the islands, where the slopes are presented more directly to the rays of the afternoon sun . . . . The higher levels of Mauna Kea (13,825 feet) and Mauna Loa (13,675 feet), Hawaii, and of Haleakala, (10,032 feet), Maui, are frequently white with snow during the colder months of the year, and it is not unusual to see snow banks on the crest of Mauna Kea or Mauna Loa, the highest peaks of the islands, even in midsummer. . . . . . It is doubtful if frost ever forms much if any below the 2,500-foot level over the entire group of islands, and rarely below the 4,000-foot level.

In summary, the strongly contrasted types of climate prevalent over different sections of the Hawaiian islands result from the presence of these land barriers, rising to various elevations above sea level, in the path of the prevalent northeast Trade Winds. Savanna climates prevail over the lower windward slopes of the higher islands. At higher elevations (between 2,500 and 6,000 to 7,000 feet) the rainfall is heavier and is more evenly distributed throughout the year. The climate is like that of the rain forest belt of the Tropics. On the highest mountains, above the belt of maximum precipitation the rainfall is less and the temperatures are lower and show greater daily and seasonal variability. The general features of tropical climates prevail, but temperature rather than rainfall is the controlling factor. These highland climates are isothermal and depend for their special characters upon elevation above sea level.

The leeward slopes of the higher domes receive lesser amounts of rainfall as sea level is approached; the climates vary from tropical highland isothermal at the highest elevations to savanna at intermediate levels and become semiarid near sea level. On Niihau (1,281 feet), dry climates everywhere prevail; the rainfall rarely exceeds 25 or 30 inches annually, and commonly is much less. The island is too low to cause the formation of permanent cloud caps over its summit.

Rainfall

The rainfall map of Kauai (fig. 2) shows that the precipitation rapidly increases from the shoreward margin of the northern and northeastern lowlands to the summit, where Waialeale (5,080 feet), near the center of the island is credited for a period extending intermittently from 1911 to 1917

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with the extraordinary annual average rainfall of 476 inches (Table 3). Waialeale therefore rivals Cherrapunji, Assam (average annual rainfall 426 inches), as a claimant for the doubtful honor of being the rainiest place on earth. The precipitation over the windward lowlands is generally more than 50 inches annually, and decreases from the northern and eastern coasts

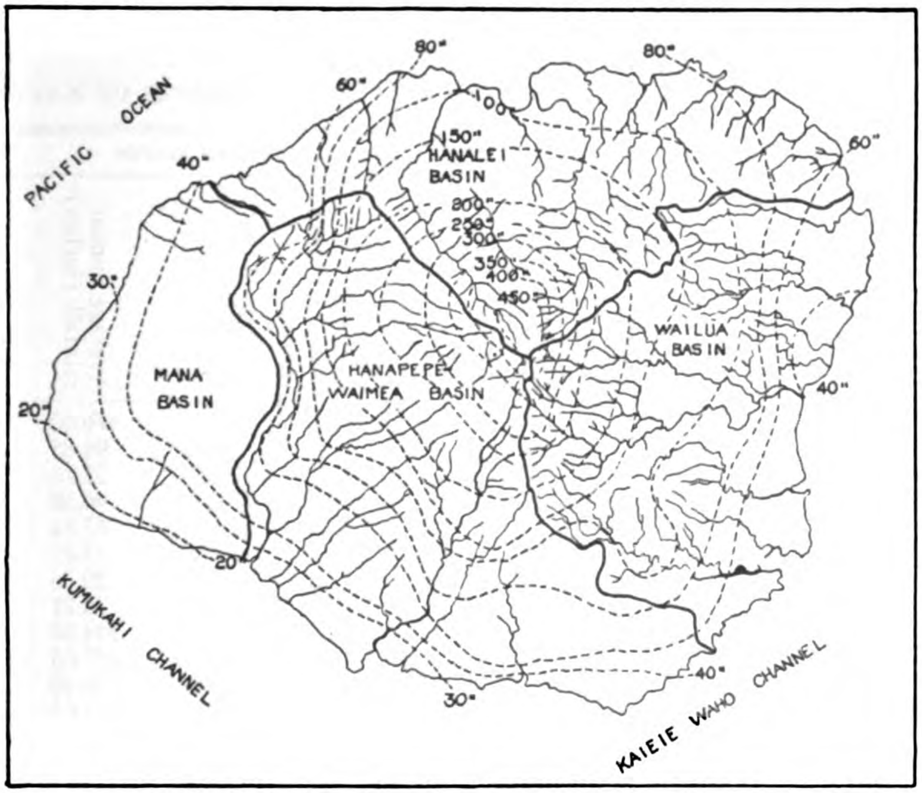

Figure 2.—Rainfall and drainage map of Kauai. Drainage from U. S. Geological Survey, Water-supply paper 318. Rainfall data from the U. S. Weather Bureau. Bounderies of drainage basins are indicated by heavy lines. Scale: 1 inch=8.85 miles.

toward the southern coast of the island. To the leeward of the summit bog, on which Waialeale is located, the rainfall rapidly lessens, and over the mountain slopes and coastal lowlands 10 to 15 miles from the center of the island, the climate is distinctly arid. Tables 1 and 2 (compiled from publications of the United States Weather Bureau) show the distribution of precipitation over Kauai. (See also fig. 2)

The rainfall records for Waialeale, the station at the summit of the island (elevation 5,080 feet), so far as they are available, are given in Table 3. These records do not include the greater part of the years 1914 and 1918, the wettest in the history of the local Weather Bureau Office. The mean rainfall for all periods covered by actual rainfall records was 1.30 inches a day, or, 476 inches a year. Unfortunately the station is very difficult of access and

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from time to time has been discontinued. When certain of the observations were made, the rain gage was found to have overflowed, so that the maximum precipitation at the station probably is not known.

The decrease in precipitation over the leeward slopes of Kauai is rapid but irregular, for strong air currents blow tongues of the cloud cap, which is so commonly present over the upper levels of the island, for some distance down the leeward canyons and over the intervening divides, and thereby

TABLE 1. RAINFALL OVER WINDWARD AND LEEWARD SLOPES OF KAUAI.

WINDWARD SLOPES					LEEWARD SLOPES				
Station	Distance from station of heaviest rainfall (miles)	Elevation (feet)	Average annual rainfall (inches)	Length of record (years)	Station	Distance from station of heaviest rainfall (miles)	Elevation (feet)	Average annual rainfall (inches)	Length of record (years)
1	10.0	10	98.50	18	8	0.0	5,075	476.00	7
2	10.5	105	89.47	8	9		3,600	94.85	6
3	10.0	125	124.91	11	10	11.1	2,550	55.73	6
4	11.5	342	70.48	33	11	5.5	3.500	46.58	5
5	7.5	635	145.83	8	12	10.0	900	67.56	12
6	8.0	700	184.09	12	13	13.0	850	15.81	7
7	4.0	1,900	198.59	8	14	13.0	150	29.36	18
8	0.0	5,075	476.00	7	15	16.5	35	22.21	17
					16	4.5	2,100	144.58	7
					17	1.5	2,080	237.05	9
					18	7.5	2,000	170.49	15
					19	4.0	1,310	111.65	14
					20	5.5	530	133.09	14

extend the belt of heavy rains beyond its normal limit. Thus may be explained the heavy precipitation recorded at leeward Stations 16-20, Table 1. Stations 16 and 19 are at or near the bottom of Olokele Canyon, Station 20 at the bottom of Hanapepe Canyon, and Stations 17 and 18 on neighboring divides. The rainy season which lasts from November through March on the leeward side and through April on the windward side, is well defined over the lowlands; at higher elevations, the precipitation is much more evenly distributed throughout the year. (See Table 2.) The mountain summits are cloud-capped, except for a few hours during the early morning or for a few days during occasional southerly or southwesterly winds. On the windward side, the base of the cloud cap generally hangs about 2,000 feet above sea level; on the leeward side, the base of the cloud is much more irregular and generally does not extend so far down the mountain sides. Within the area more or less continuously covered by the cloud cap, rain falls most of the time. That portion of this area comprising the summit plateau has low relief and relatively poor drainage, hence nearly all of it is swampy.

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TABLE 2. RAINFALL BY MONTHS OVER COASTAL LOWLANDS AND MOUNTAIN SLOPES OF KAUAI. (IN INCHES.)

Station[a]	Elevation (feet)	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	200	6.72	3.77	7.66	3.85	3.70	2.80	2.73	3.41	5.17	3.64	5.28	6.38
2	10	6.48	9.88	15.02	7.90	6.35	5.28	6.67	8.35	6.40	7.61	9.24	9.31
3	155	4.04	3.45	4.94	1.94	1.42	1.19	1.18	1.22	2.04	1.83	2.91	3.20
4	30	4.20	1.59	5.49	1.08	1.33	0.69	0.49	0.61	1.82	1.51	1.87	3.12
5	700	12.89	14.25	21.61	20.89	15.10	12.28	12.80	14.49	11.86	11.18	18.34	18.40
6	1900	18.02	10.28	19.98	17.80	18.04	14.05	15.61	13.56	16.97	14.29	21.05	18.94
7	2080	19.02	10.70	16.92	20.15	17.79	18.78	22.51	19.08	20.71	19.14	27.08	27.17
8	2100	12.72	7.83	12.44	12.06	10.82	9.53	10.49	10.30	12.02	12.24	17.50	16.53

[a] Stations 1, 2, windward coastal plains; 3, 4, leeward coastal plains; 5, 6, windward mountain slopes; 7, 8, leeward mountain slopes.

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A striking feature of the Hawaiian rainfall is its large annual variability. (See Tables 3 and 4.) The Kona storms materially affect the annual precipitation, especially over the leeward slopes, as the precipitation during a single storm may exceed the annual average for the region. Table 4 gives the maximum and the minimum annual rainfall recorded at certain stations on Kauai, and a few maxima measured for 24-hour periods.

TABLE 3. ANNUAL RAINFALL AT WAIALEALE, KAUAI (IN INCHES).

1911	
Aug.-Oct.	134.00
Nov.-Dec.	86.00
1912 (Jan. 6, 1912-Jan. 11, 1913)	
Jan.-Mar.	90.00
Apr.-June	82.20
July-Sept.	78.50
Oct.-Nov.	58.00
Dec.	105.50
Total	414.20
1913 (Jan. 11, 1913-Jan. 13, 1914)	
Jan.-Mar.	60.00
Apr.-May	94.00
June-July	77.00
Aug.-Sept.	61.50
Oct.	23.50
Nov.-Dec.	135.00
Total	451.00
1914	
Jan.-Mar.	30.00
April-July	134.00
(Gage found overflowing. Station discontinued till May 21, 1915.)	
1915	
June-Sept.	197.00
Oct.-Dec.	217.00
(Precipitation May 21, 1915, to May 21, 1916, 561.0 inches.)	
1916 (Jan. 12, 1916-Jan. 4, 1917)	
Jan.-May	147.00
June-July	75.00
Aug.-Oct.	109.00
Nov.-Dec.	190.00
Total	521.00
1917	
Jan.-Apr.	166.00
May-Aug.	109.00
1919 (June-Dec.)	204.00
1920	549.00
1921	367.00
1922	452.00
1923	360.00
1924 (Jan.-July)	228.00
1925 (Jan.-July)	362.00

TABLE 4. RECORDED RAINFALL AT CERTAIN STATIONS ON KAUAI.

Station		Elevation (feet)	Minimum annual rainfall (inches)	Date	Maximum annual rainfall (inches)	Date	Elevation (feet)	Rainfall 24-hour maximum (inches)
1	Windward lowland	10	64.68	1906	161.45	1902	140	9.52
2	Windward lowland	200	32.66	1912	71.50	1918	250	11.40
3	Leeward lowland	8	5.97	1912	38.71	1907	700	16.00
4	Leeward lowland	150	14.35	1912	43.17	1907	1055	10.52
5	Windward mountains	700	126.54	1908	249.83	1916	3500	15.10
6	Windward mountains	1900	155.82	1912	237.35	1918	3723	24.40
7	Leeward mountains	2080	189.23	1923	303.20	1906	....	....
8	Summit of island	5080	367.00	1921	549.00	1920	....	....

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Temperature

The only temperature records available for Kauai are from six stations on the lowlands. These stations, of course, show small differences between the mean monthly maxima and the mean monthly minima. The mean average temperatures are slightly higher on the leeward than on the windward side of the island. (See Table 5.)

TABLE 5. TEMPERATURES AT STATIONS ON KAUAI.

STATION		MEAN ANNUAL TEMPERATURE RANGES	MEAN ANNUAL TEMPERATURE	COLDEST MONTH	WARMEST MONTH
Kilauea	Windward	68.5 - 75.3	72.4	January	July
Kealia	Windward	62.2 - 77.2	73.5	January	July-August
Lihue	Windward	68.0 - 76.5	72.5	January	July
Koloa	Leeward	69.2 - 76.7	73.1	January	September
Makaweli	Leeward	71.0 - 78.3	74.9	January	July
Mana Pump	Leeward	69.3 - 77.8	73.7	January	July

The temperatures over the highlands decrease, month for month, as elevation increases. On the mountain slopes, above 3,000 feet, frost is not uncommon during the rainy season; snow has not been observed. Unfortunately, no meteorological records are available regarding the temperatures in the highlands of Kauai, though they are probably like those at upland stations on other islands. On Maui, the mean temperature ranges at Keania Valley (altitude 1,600 feet) is 65.0° to 70.7°; at Kula Sanitarium (altitude 2,700 feet), 60.4° to 66.8°. On the island of Hawaii, the mean temperature at Volcano Observatory (altitude 3,984 feet) is 57.8° to 62.7°; at Humuula (altitude 6,685 feet) 48.5° to 55.5°.

Relation of Relief to Clouds and Rainfall

The relief of eastern and northeastern Kauai exerts an important influence upon the present distribution of rainfall over the windward slopes. The northern and eastern mountains rise abruptly from the lowlands to elevations of 2,000 to 5,100 feet. The moisture-laden trades, sweeping across the low country, are confronted by this barrier, which forces them to rise suddenly to levels of lower temperatures. Continuous condensation of the moisture follows, and a cloud cap is formed over the highlands above an elevation of 2,000 or 2,500 feet during most of the time that the Trade Winds blow. The position of the cloud cap is apparently controlled by the average temperature and the strength of the wind. On warm days, when the temperatures over the lowlands exceed 85°, the clouds rise from 1,000 to 2,000 feet above their normal level, and cover only the highest summits of the dome. At times when the wind velocity falls below the normal 10 to 12 miles an hour, the

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cloud cap rises or disappears entirely for a few hours. When the occasional southerly or southwesterly winds prevail, the cloud cap is generally dissipated for periods of a few days, the longest intervals during which the highland summits are visible.

The condensation of the water vapor which takes place when the Trade Winds are forced to cooler levels not only results in cloud formation, but also produces more or less continuous heavy precipitation over the higher windward slopes and over the summit plateau. Because of this suddenness of the upward deflection of the air currents, the increase in precipitation along the mountain slopes is rapid, as is shown in Table 6.

TABLE 6. DISTRIBUTION OF PRECIPITATION OVER NORTHERN AND EASTERN KAUAI.

STATION	ELEVATION (FEET)	AVERAGE ANNUAL PRECIPITATION (INCHES)	LENGTH OF RECORD (YEARS)
Northern Kauai:			
Outer portion of coastal lowland			
1	10	98.50	18
2	105	89.47	8
3	342	70.48	33
Inner margin of lowland			
4	635	145.83	8
Canyons and mountain slopes			
5	125	124.91	11
6	700	184.00	12
7	1900	198.59	8
8	5075	473.00	7
Eastern Kauai:			
Outer portion of lowland			
9	14	40.81	19
10	200	55.11	14
11	350	65.53	9
12	400	60.15	16
Inner margin of lowland and lower mountain slopes			
13	500	119.31	3
14	650	125.85	4
15	725	91.84	14
16	835	125.18	11
17	911	108.85	3
Higher mountain slopes			
18	1900	198.59	8
19	5080	473.00	7

Hamrick (29) has discussed the causes of the formation of these cloud caps on the Koolau Mountains, Oahu, which closely resemble the steep slopes of northern and eastern Kauai. On theoretical grounds he placed the base of the cloud cap at 2,040 feet, a figure which closely approximates the actual conditions.

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Because of the wide plains on windward Kauai and eastern Oahu the rainfall is less at a greater distance from the shore than on the other domes of similar or greater elevation, and the rate of increase of precipitation is more rapid over the very steep windward slopes of these mountains than over those having the more normal, gentler slopes.

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GEOMORPHOLOGY

FORM AND SIZE OF KAUAI AND NIIHAU

The islands of Kauai and Niihau are the highest summits of one of the principal volcanic mountains of the Hawaiian range, and represent accumulations about the two major eruptive centers which have appeared above sea level. Soundings may reveal submerged centers, especially off the southern end of Niihau, where comparatively few depths have been measured. The greater portion of the mountain, of course, is submerged; the depths of the Pacific surrounding its base range from 2,000 to 2,500 fathoms, whereas the highest elevation on Kauai is slightly over 5,000 feet and on Niihau about 1,300 feet above sea level. The area of the base of the mountain cannot be accurately determined; but the long diameter, if the cinder cone, Kaulu, 19 miles southwest of Niihau be a part of the structure, must exceed 100 miles and the short diameter 40 to 50 miles. The major and minor diameters of Kauai are 32 and 22 miles respectively and of Niihau 18 and 5 miles. Niihau was originally larger and higher than at present; marine abrasion and downfaulting have caused the disappearance of more than half of the island. A discussion of the surface relief applies therefore to only a small part of the volcanic edifices. Little is known of the structure of the submerged part of the mountain. (See p. 50.)

FEATURES OF HAWAIIAN LAVA DOMES

In this report, I shall use the term "lava dome" as defined by Daly (11, pp. 135, 136):

> The greater masses of lava, which in the form of many individual flows, have issued from a central vent [or, as Daly (14) has demonstrated since, from a series of more or less centrally located principal fissures] in the proper abundance and proper directions to build a dome-shaped pile of lava . . . . Such bodies are of exogenous growth and are thus contrasted genetically as well as in size with the plug-domes.

Von Wolf (64, p. 448) calls such mountains "Lavavulkane" or preferably "Schildvulkane," and recognizes two classes: (1) the Dyngju type of Reck and von Knebel which is found in exceptional abundance in Iceland; (2) the Hawaiian type. As size is the sole basis of this classification, the distinction seems unnecessary; the smaller Hawaiian domes, west Molokai and Kahoolawe, do not greatly exceed the dimensions of some domes of the Dyngju type. The coalescence of two or more of these lava domes forms a compound lava volcano; the various mountains may be joined together above sea level as are Hawaii (built of at least five domes), Oahu and Maui (each built of two domes); or they may be connected below sea level as are Maui, Molokai, Lanai, and Kahoolawe, or Kauai and Niihau. It seems highly probable that the Oahu doublet has been joined with the great compound Maui volcano

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below sea level to form a single mountain of huge dimensions and mass (36, pp. 149-150.)

At the close of their last principal eruptive periods, the Kauai and Niihau domes probably resembled in form the young volcanoes of Hawaii: Mauna Loa, Kilauea, Mauna Kea, and Hualalai.

As typified by Mauna Loa and Hualalai, the completed or nearly completed lava dome is a land form of simple outline, composed of more or less homogeneous layered rocks which dip seaward at low angles from the major eruptive area or center or from other openings along the flanks of the volcano. The changes in relief which follow the cessation of volcanic activity are produced chiefly by fluvial and marine erosion, by the gravitative transfer of rock or of the soil cover, and by faulting. Changes of level also may be of importance and the sporadic renewal of volcanic activity at local centers frequently adds new lavas and deposits of ejectamenta to the erosional surface. In colder latitudes, glaciation may modify the pre-existing relief.

Comparison with Mauna Loa and Hualalai indicates that at the close of the last principal eruptive periods Kauai and Niihau were somewhat symmetrical, gently sloping mountains, on whose surfaces were imposed numerous parasitic cinder cones. Permanent valleys were few and unimportant, and sea cliffs, if existing, were low. The topography of the central eruptive area cannot be determined on either island. The principal center on Kauai is either concealed beneath the thick jungle cover over the highlands or has disappeared wholly or in part as the result of the downfaulting and deep erosion of a large section of the eastern part of the dome. Engulfment and marine erosion have caused the disappearance of the major eruptive center on Niihau.

The height of Kauai at the close of the last major eruptive period probably was about the same as at present, slightly more than 5,000 feet, the maximum elevation on the largest remnant of the constructional surface. If any reduction in height has taken place through erosion, crushing of the vesicular and cavernous lavas, or subsidence, this loss probably has been compensated by an emergence of the island which has exceeded 500 feet. The periphery on the other hand has been reduced by wave attack. Judging from the extent of the sea cliffing, the original maximum diameter of the island must have been approximately 40 miles, whereas the present greatest diameter is 32 miles. Niihau has lost notably in size and elevation; at the close of the principal eruptive period, the dimensions of the volcano probably were about 15 by 10 miles and its elevation at least 2,000 or 3,000 feet.

PHYSIOGRAPHIC SUBDIVISIONS OF KAUAI

The initial, simple, dome-like contour of Kauai has been greatly modified by long continued fluvial and marine erosion, by extensive downfaulting, by

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changes of level of considerable magnitude, and by explosive volcanic eruptions which took place from subordinate vents after most of the present topographic features had been developed. Four major divisions of the present highly diversified relief may be recognized (fig. 3): (1) The summit plateau; (2) the dissected highland; (3) the elevated wave-cut platform of eastern Kauai; (4) the constructional plain lying west of the Waimea River.

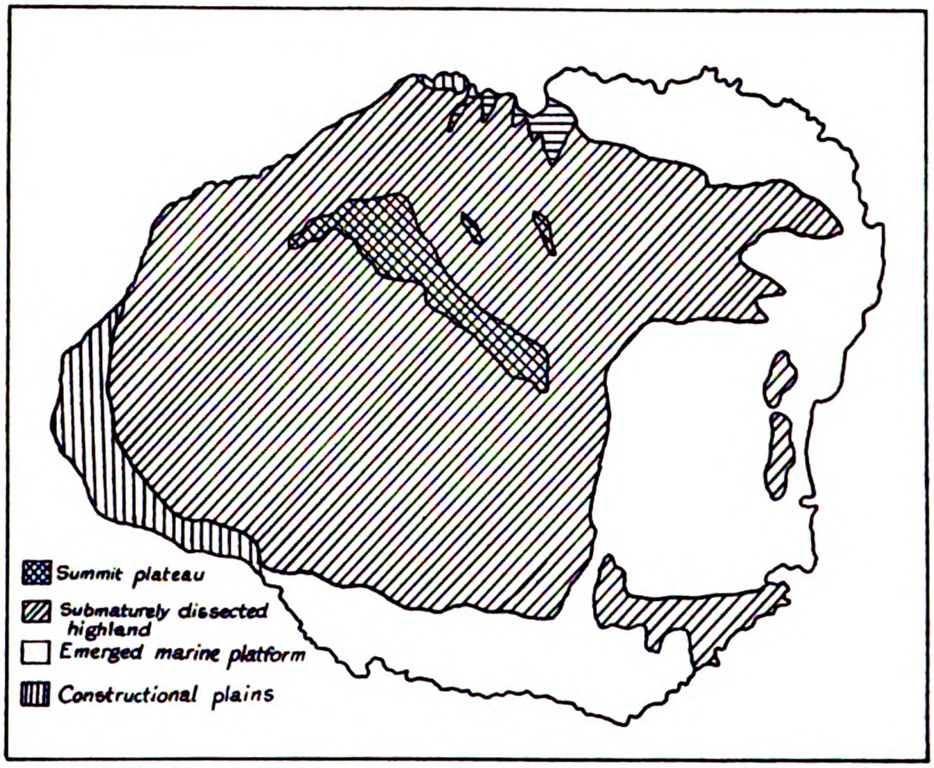

FIGURE 3.—Physiographic subdivisions of Kauai. Scale: 1 inch=8.8 miles.

SUMMIT PLATEAU

The summit plateau (Alakai Swamp) is the principal remnant of the constructional surface of the Kauai dome. This sector, which has an area of nearly 30 square miles (about one-twentieth of the island), extends for 10 miles northwestward from the center of the island; its northwestern boundary is 2.5 to 3 miles from the coast. The deep gorge of the Koaie River flowing southwestward from the plateau nearly bisects it. Northwest of this gorge, the average width of the plateau is about 2.5 miles; to the southeast, the average width is about 1.5 miles. The elevation of the sector decreases from 5,000 feet along its eastern margin to 4,000 feet along its northwestern margin. On the northwest, northeast, east, and south, the limits of the plateau are sharply defined by great palis, the cliffed walls and heads of the major canyons. On the southwest side, the upstream growth of the canyons has

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been slower and more irregular, owing to the lesser precipitation over the leeward slopes of the dome; hence the southwest margin is ill defined. There is, however, a rather sharp change in slope between this sector and the deeply eroded portion of the highland to the west. As is shown by the direction of flow of most of the streams, the general slope of the plateau is southwest. The eastern extremity slopes north and east, and from this section flow the headwaters of the principal rivers of northern and eastern Kauai.

The surface of the plateau is traversed by ill-defined drainage lines, which have eroded broad, shallow valleys. Northwest of the deep Koaie gorge, these valleys are somewhat deeper than to the southeast, apparently because of the somewhat higher surface gradient of the former area. Broad, tabular interfluves separate the valleys. Though the topography of the region is youthful, the valley forms are those developed in an upland region of low slope where downward erosion by the small, headward tributaries of the principal streams of the island is relatively slow. Beyond the limits of the plateau, valley cutting has proceeded much more rapidly, hence there is a striking contrast between the gentle rolling topography of the plateau and the highly differentiated relief of the rest of the highland (Pl. I, *B*).

On the summit plateau, rain falls almost constantly. (See pp. 15-16.) Because of the low relief, drainage is slow, and large areas of the surface are swampy. Low ridges and eminences standing above the general surface are better drained, but, even on these, water stands more or less permanently in every depression. Except on these higher areas, the plateau is practically treeless; the areas separating the pools of water are covered with grass, sphagnum mosses, lichens, sedges, a few shrubs, and other types of small plants. Jungle forest, similar to that of the rainier section of the dissected highland, covers the higher elevations of the plateau. Owing to the extent of the swamp and to the almost ever-present cloud blanket, travel over the plateau is difficult. Field observations regarding the morphologic and structural relations are difficult to procure; exposures of undecomposed rocks are absent on the summit plateau, and heavy vegetation covers the surrounding, more dissected areas where sections of the lavas might be found.

The summit plateau is a remnant of the constructional surface of the Kauai dome. Though the structural relationships cannot be definitely ascertained owing to difficulties of exploration, it is evident that the surface of the area in a general way lies parallel to the bedding of the lavas exposed in the gorges and canyons of the adjacent, more dissected portions of the highland. Also it is impossible to suggest any other way in which so extensive an area of low relief could be developed near the summit of a deeply eroded volcanic mountain. From the geomorphic evidence, therefore, it is apparent that the headward advance of the streams, especially on the leeward side of Kauai, is not yet completed, and that a small area of the original surface, only

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slightly modified by erosion, has been preserved. Eventually, the upstream growth of the cliffed canyons will reduce the central portion of the island to a series of sharp peaks, such as are present in many of the older, still more deeply eroded lava domes in various parts of the world.

Other smaller remnants of the constructional surface are preserved as seaward-sloping areas of low relief forming parts of the divides between certain of the canyons of northern and northeastern Kauai. While I was unable to visit any of these smaller remnants, it was apparent from the descriptions given by others and from distant views that their topography is similar to that of the summit plateau.

Though water stands in practically every depression in the plateau surfaces, little vegetation accumulates; the average high temperatures cause rather rapid decay of most of the dead plant tissues. Organic acids are thus added abundantly to the subsurface waters which percolate downward through the porous and cavernous lavas.

Dissected Highland

At the close of the principal volcanic period few valleys of any consequence existed on Kauai. The frequency of eruptions was sufficient to prevent active stream erosion. With the cessation of volcanic activity, waters, penetrating through the lavas, gradually decomposed them, and the surface run-off, concentrated in many depressions, began to incise narrow gorges into the mountain slopes. Assuming a distribution of rainfall similar to that of the present, the heavier precipitation over the windward section of the island caused the formation of a greater number of streams than on the leeward side. Near the summit of the dome, the streamlets were unable to materially corrade the lavas. The elevations at which valley cutting was initiated were in general higher on the windward than on the leeward flanks of the island, because of the more active weathering of the lavas, and the greater numbers and volumes of the streams. The valleys at first were shallow, steep-walled trenches, between which were practically undissected conic sections of the constructional surface. It is probable that most of these valleys did not enter the ocean at grade because in the early erosional stages, wave cutting apparently is more effective than stream erosion. For example, on windward Mauna Kea, one of the most recently extinct Hawaiian volcanoes, the streams tumble a hundred or so feet down sea cliffs into the ocean. As erosion progressed, the windward streams rapidly deepened their channels to grade. Along the leeward coast, downcutting has been so much slower that the mouths of many of the gorges still hang some distance above the base of the great cliffs.

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The early erosional topography of Kauai may be compared with that of eastern Maui (Haleakala) or of Mauna Kea and Hualalai, all recently extinct volcanoes.

In the zone of heaviest rainfall on the windward slopes of Kauai, the multiplication of tributaries has gradually produced more highly complicated drainage patterns and consequently finer textured topography. The dissection of the seaward portions of the interfluves has taken place more slowly. On the windward side, the crests are sharp throughout their entire length; on the leeward side, they are ridge form in the interior of the island, and gradually become tabular near the outer margin of the highland (fig. 4). The topography at equivalent elevations on the leeward side is distinctly coarser textured. Study of East Maui and Mauna Kea shows that the asymmetrical

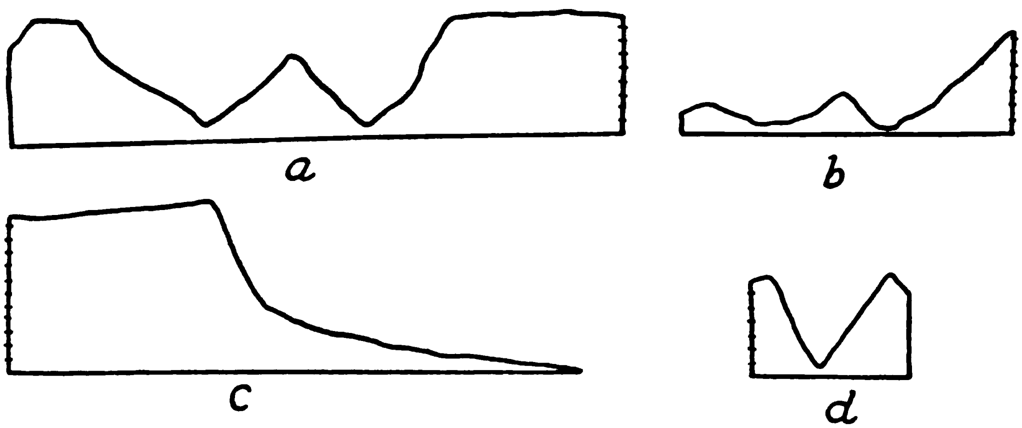

FIGURE 4.—Cross-sections (*a*, *b*, *d*,) of valleys and interfluves and profile of valley (*c*) of northern Kauai. Vertical scale: 1 space=250 feet; approximate horizontal scale: 1 inch=2 miles.

evolution of the erosional relief on the windward and leeward sides of mountains located in the belts of savanna climates begins in the early posteruptive stages; on the older domes it remains a striking feature in spite of the extensive denudation of all sections. On Kauai, this asymmetry has been accentuated because of two special conditions: (1) an abnormal development of the drainage on the western side of the island due to the deflection of a part of the streams by a fault zone along which the Waimea River runs (p. 30); (2) the downfaulting of a large section of the eastern part of the dome (p. 30).

Normally, a consequent "wheel-spoke" drainage and valley or canyon system is developed on conical mountains such as explosive volcanoes or lava domes. The major drainage lines on Kauai flow from the summit plateau and the immediately adjacent ridges, and follow roughly radial paths to the shore line. On the western side of the island, the north-south Waimea fault zone

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(p. 30) existed, and apparently the block to the west stood higher than that to the east of the zone of dislocation. The streams from the heavily watered summit plateau were deflected by the scarp, and became tributary to a major channel (the Waimea River), flowing southward to the ocean (fig. 8, *a*). To the west of the river, the drainage again is radial. Other abnormalities, probably due to faulting, are to be found in some of the drainage lines of eastern Kauai.

The major streams and their principal tributaries have incised deep, narrow canyons into the heart of the dome, and, in the long course of the post-volcanic period, have aided in the very extensive destruction of the constructional surface. The stage of dissection naturally is most advanced on the windward (northern and northeastern) sides of the island; the minimum effects of stream erosion are to be observed west of Waimea Canyon, owing to special conditions.

Above the heads of the great canyons, the tributaries, flowing over the gently sloping constructional surface, have not greatly eroded it; and a small, only slightly dissected remnant of this surface has been preserved as the summit plateau of the island. Over most of the plateau, the valleys are inconspicuous. On the northwestern, eastern, and southern sides, the streamlets tumble down the steep-walled or cliffed heads and sides of the canyons into the trunk streams below. On the southwestern side, toward which most of the plateau slopes, the headward growth of the major canyons has been slower. The plateau drainage has united into a number of streams powerful enough to cut steep-walled gorges several hundred feet deep into the margin of the area but these are much shallower than the principal canyons which they join. The abundance of these hanging valleys is one of the most striking features of the relief of Kauai and the other dissected lava domes in Hawaii (Pls. I, *B;* II, *B*). Thus, on the leeward side, there is a transition zone between the relatively undissected summit plateau and the belt of the great canyons to the southwest (Pl. I, *B*); this difference in the evolution of the erosional relief is of course a reflection of the asymmetric distribution of rainfall over the windward and leeward sections of the island.

The continued headward growth of the main canyons will eventually result in the destruction of the summit plateau; the central portion of the island will then consist of a group of jagged peaks instead of the flattish area now present.

The canyons are narrow, roughly radial trenches, 1,000 to 3,000 feet in depth, a maximum of 10 or 12 miles in length, and 1 or 2 miles in average width; their heads are huge, steep-walled amphitheaters which bear some resemblance to glacial cirques in their rounded ground plan, the general sheerness of their walls, and the steepening of the upper portions of their walls. A few valleys even have flattish floors (fig. 4). Freeman (25) has suggested

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the term "pseudo-cirque" for such amphitheaters, but I have objected to this on the ground that it is undesirable to apply terms definitely associated with certain geological process to forms evolved by a totally different process (35). The name "amphitheater head" or "amphitheater valley head" is satisfactory.

In the rainy sections of the highland, tributary streamlets, plunging from the summit plateau or from the sharp-crested interfluves, have deeply channelled the canyon walls, and have produced a highly complex "organ-pipe topography." Specially resistant lavas within the igneous complex have not been cut back by the streams as rapidly as weaker flows, hence the waters, in their descent into the major drainage lines, commonly fall on to a number of narrow rock benches. Into these benches, the streams have cut shallow basins and have undercut to some extent the rocks immediately above the benches. The furrows through which the falls pass are deep; between them are huge, nearly vertical columns or pipes, many of which in turn have been fluted or divided into smaller pipes by minor streamlets. Some of the falls are permanent, others appear only after heavy rains, but water flows through the channels sufficiently often to prevent the growth of much vegetation over the lavas. Hence the fall lines appear as barren streaks of black rock through the dense jungle tapestry which covers practically all of the canyon walls in the rainy section. During and after heavy rains, in nearly every furrow is a silvery ribbon of water tumbling for hundreds of feet through the green of the forest cover, its fall broken at various levels by projecting lava benches or masked for a few feet by a specially thick tangle of vegetation. The charm of the tropical landscape is thereby increased a hundred fold. (See Pl. III, *C*.)

In the drier, lower reaches of the canyons, minor streams are fewer, and the "organ-pipe" topography gradually disappears. High, nearly vertical cliffs form long stretches of the canyon walls (Pl. III, *A*). Cliff-bench profiles, caused by the difference in resistance of the lavas to erosion, are common. Vesicular ropy flows and highly brecciated clinkery flow tops form weak layers along which undermining proceeds with maximum rapidity. Above these layers collapse of insufficiently supported rock masses occasionally takes place. In Waimea Canyon in particular, there is so marked a development of cliff-bench topography that this gorge is frequently called a miniature Grand Canyon. Viewed from its western rim, the canyon does bear a rather striking resemblance to the master gorge, though of course it lacks the incomparable coloring (Pl. I, *B*).

The depth and narrowness of the canyons and the steepness of their walls result from the speed at which down cutting has taken place and the average high resistance of the lavas to erosion. At the surface, the lavas are deeply weathered, and the streams rapidly cut through this oxidized zone to fresher rocks below. Frost does not form sufficiently often in the highlands of Kauai

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to be an important agent of rock disintegration; at lower elevations freezing temperatures never occur. Changes of temperature also are slight even at the highest elevations, and have virtually no effect upon the rocks. Because of the abundant precipitation, the average high temperatures, and the extremely porous structure of the lavas, chemical decay proceeds rapidly; atmospheric and ground water solutions readily penetrate and attack the rocks, and, on the windward side of the island in particular, have altered them to considerable depths. The highly vesicular and brecciated zones within the flows provide avenues of specially easy access for the subsurface circulation; hence, where rocks possess these structures, weathering has proceeded rapidly. As the general peripheral dip of the flows together with the great numbers of openings in them allows for the active migration of underground waters, the frequent acquisitions of oxidizing solutions are readily taken care of. Rapid decay of abundant vegetation in the warm, humid climate adds great quantities of organic acids to the solutions, and increases their efficiency as agents of rock weathering especially in the surface zones. On the summit plateaus and on the windward side of Kauai, decomposition of the lavas had proceeded far below the surface; on the leeward side, the depth of the oxidized zone is much less. Mechanical disintegration is at a minimum, except in the channels of the streams, along the shore lines, and in places where landsliding of large rock masses takes place.

The major streams are large and have moderately steep gradients; hence they are rapidly deepening their canyons and eroding them headwards. Sapping by weathering and running water takes place actively along weak zones in the lavas. Landsliding is common and is the principal factor in the widening and headward growth of the valleys, the steepening of their walls, and the supplying of rock fragments to the streams. In the areas of heavy rainfall, the abundant and speedy run-off normally should cause active solifluction and should keep the slopes relatively free from loose material, but even the steepest slopes are covered with dense vegetation which retards the movement of soil and also is effective in preventing the slump of larger, more or less unstable masses of weathered rock. Solifluction is greatly accelerated during the rainy season, and the swollen streams carry tremendous quantities of detritus washed into them from the steep slopes. Frequent landsliding of course takes place even where the vegetation is heaviest; great scars along the canyon walls record such collapse. Where the vegetation is luxuriant, these scars are quickly obscured. In the drier sections, the rate of weathering is slower and sapping along weak zones takes place less rapidly. The plant cover is broken, hence there is little to check the slump of loose débris, but the amount of material available for transfer is infinitely less than in the rainy sections.

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SUBDIVISIONS OF THE DISSECTED HIGHLAND

Because of certain marked topographic differences, the highly dissected portion of the island surrounding the summit plateau may be divided into five segments or parts of segments (fig. 3 and p. 45) as follows:

1. The segment between the western rim of Wainiha Canyon and the Anahola Mountains—the eastern part of the Hanalei drainage basin.
2. The area between the Anahola Mountains and Haupu Ridge—the mountainous section of the Wailua drainage basin.
3. The segment between Haupu Ridge and the western rim of Waimea Canyon—the Hanapepe-Waimea drainage basin.
4. The area west of Waimea Canyon and south of Nualolo Canyon, northern Kauai—a part of the Mana drainage basin.
5. The area between the west rim of Wainiha Canyon and Nualolo Canyon, northern Kauai—the western portion of the Hanalei drainage basin.

1. The most heavily watered section of Kauai is the rugged, submaturely dissected highland belt on the northern side between the west rim of Wainiha Canyon and the eastern end of the Anahola Mountains. West of the Kilauea River, the elevations of many of the mountain summits range from 3,000 to 5,000 feet; at the east end of the Anahola Range, they decrease to about 2,000 feet. The heaviest precipitation falls over the western part of the segment; in that part are the largest streams on the island, streams which have the greatest number of tributaries (fig. 5) and fluctuate least in their volumes. Though the topography of the whole area is submature, the difference in rainfall and in the size and number of the streams is reflected in the much greater dissection of the western half where the most stupendous canyons on the island are located. The larger of these great gorges have been eroded headward almost to the center of the dome. The interfluves are steep and narrow, and are deeply furrowed by scores of streamlets plunging down their sides; the crests are sharply serrated throughout their length (Pl. IV, *A*), except for occasional small, flattish areas which are remnants of the original constructional surface of the dome (fig. 4). In the western part of the segment, the canyon walls are covered by an almost impenetrable jungle tapestry; to the east, where less rain falls, the vegetation is not so dense.

At the base of the mountains east of Hanalei River is a wave-cut platform in places 3 and 4 miles in width, standing about 500 feet above sea level along its inner margin (Pl. IV, *B*). The streams which formerly flowed into the ocean at the mouths of the canyon have been extended across this plain and have cut deep, narrow trenches into it.

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2. In the segment of eastern Kauai between the Anahola Mountains and Haupu Ridge, the development of a great volcanic sink has materially affected the topographic evolution, and has produced striking asymmetry in the east-west cross section of the island (figs. 6, 7). The magnitude of the

FIGURE 5.—Drainage map of a portion of northern Kauai.

original engulfed mass cannot be determined because subsequent erosion has greatly modified the whole of this area. Streams have gnawed huge canyons into parts of the walls, the floor of the depression has been bevelled off by waves, and the wave-cut platform has been elevated so that its inner margin now stands about 500 feet above sea level. At present, the floor

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of the Kauai sink measures 6½ miles in an east-west direction and 9 miles in a north-south direction; the dimensions from rim to rim are 10 miles east-west and 12 miles north-south. The highest point on the western wall is about 4,000 feet above the base, on the northern wall about 1,600 feet, on the eastern wall about 1,000 feet, and on the south wall about 2,000 feet (fig. 7).

Due to this engulfment, the great canyons bordering the summit plateau are short as compared with those in the segment first described, but have been eroded to similar depths. Before the emergence of the marine platform, the streams ran directly into the ocean, but now they flow for most of their lengths in valleys eroded into the wave-cut structure. Since the rain-

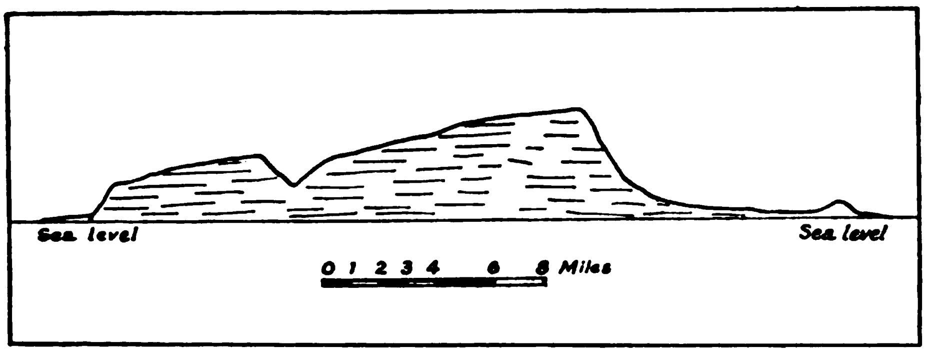

FIGURE 6.—East-west cross-section through the island of Kauai. Vertical scale: 1/10 in. = 1,000 ft.

fall over the higher slopes of this segment is only slightly less than over the adjacent segment to the north, the development of the drainage systems and character of the erosional relief in these two parts of the dissected highland is similar (Pl. IV *C*).

The parts of the highland now separated from the main area, Haupu Ridge on the south and the two lower ridges paralleling the eastern shore (Nonou and Kalepa), receive much less rain, and consequently have suffered relatively little erosion by streams (Pl. V, *B*).

3. The area lying between Haupu Ridge and Waimea Canyon is on the southern, leeward side of Kauai; most of it therefore is less heavily watered than either of the segments previously described. The precipitation is very heavy over the higher elevations, but decreases to 30 or 40 inches along the sea coast; also, more rain falls over the eastern than over the western part of the segment. The reflection of the lighter precipitation is shown in the less advanced stage of the erosional relief, as compared with that of highland of northern and eastern Kauai. The greater part of the summit plateau slopes to the southwest, and most of the run-off from its surface flows across this segment to the ocean (fig. 2). The major streams therefore have eroded huge canyons, but, since the volume and erosive power of the streams are less

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than in the windward areas, the canyons are not so large nor has their headward growth proceeded so far toward the center of the island (Pls. I, *B;* III, *A*). In the eastern part of the area, the relief is more highly differential than in the western part because of the heavier rainfall and the more numerous and larger streams. The streams, having their source below the

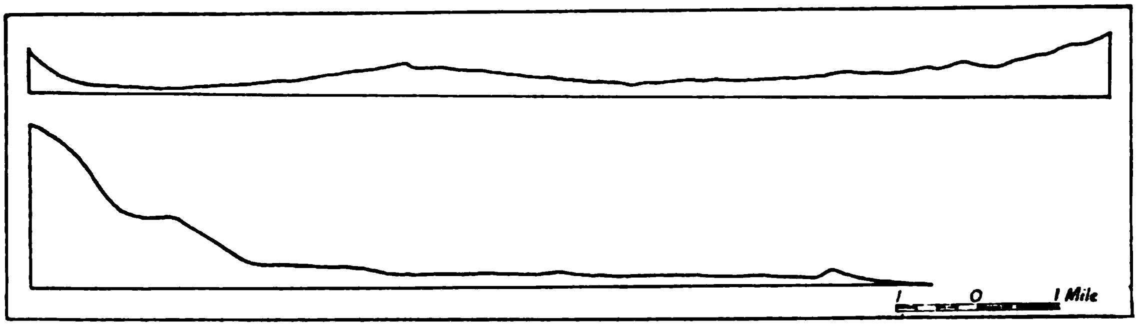

FIGURE 7.—East-west and north-south cross-sections through the volcanic sink, eastern Kauai.

margins of the summit plateau are small, and many of them are intermittent; their gorges also are small as compared with those of the main rivers.

In the higher portions of the leeward mountains, the drainage pattern is complex and the divides between the streams are steeply sloping, narrow crested ridges (Pl. III, *B*). Toward the sea coast, where the tributaries are fewer and erosion slower, the interfluves are broad and tabular in form.

The most striking feature of the segment is the Waimea drainage. The streams flowing from the summit plateau toward the western and southwestern sides of the island have been deflected by a north-south fault which has caused them to become tributary to a master channel following the general course of the dislocation. The drainage pattern is distinctly asymmetrical, since practically all of the tributaries enter from the eastern side (fig. 8, a). The trunk stream and each of its principal branches have cut great, cliff-walled canyons, into which open many hanging valleys of tributary streams (Pl. I, *B*). Since these streams have smaller volumes than those flowing from the summit plateau in the eastern part of the segment, their canyons are also smaller in size, and have not been eroded headward so far toward the center of the island. A number of small streams, heading below the summit plateau, also are tributary to the Waimea River. These have eroded short but deep cliff-walled gorges. Along the outer margin of the area, the uplift of the wave-cut platform has caused the extension of drainage which formerly flowed directly into the ocean from the mouths of the canyons.

4. As none of the drainage from the summit plateau reaches the western and southwestern coasts, the streams between the Waimea River and Nualolo Canyon derive most of their water supply from the scanty rains which fall

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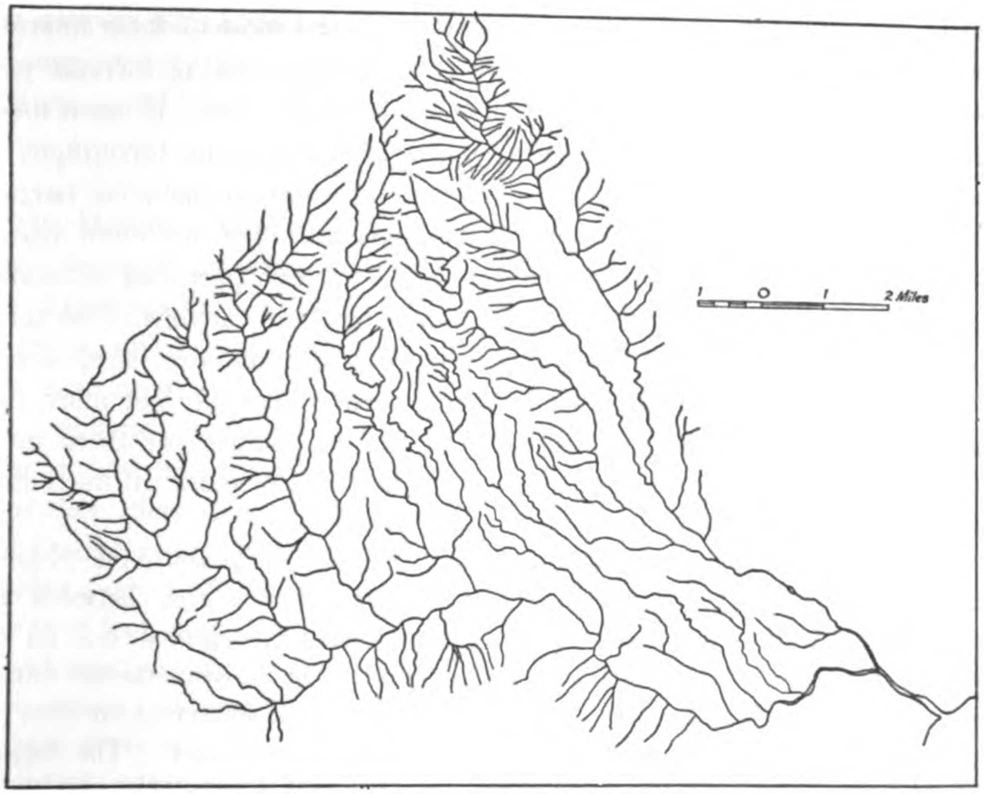
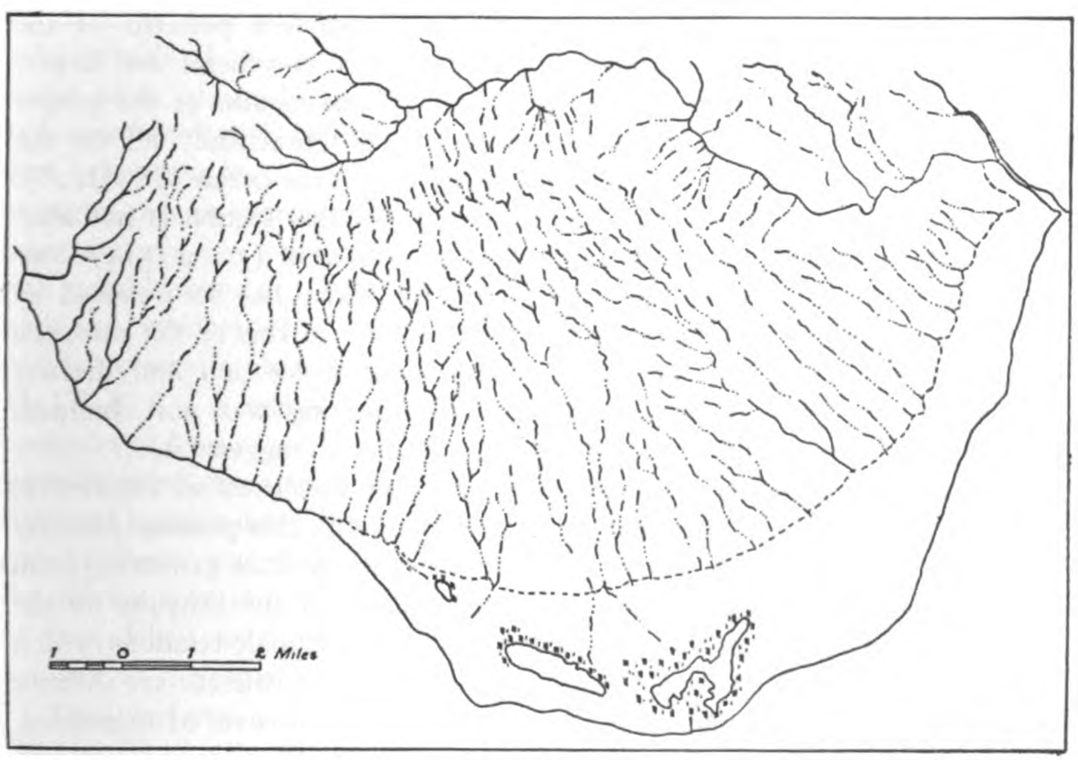


a



b

FIGURE 8.—*a*, The Waimea drainage system, southern Kauai; *b*, drainage systems in the Mana Basin, western Kauai. North is toward the left. (See plate xiii.)

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over the area (fig. 8, b). The streams are small, and most of them intermittent; they flow mainly during the rainy season, when raging torrents pour down the gorges for a few days or a few weeks at the most. Erosion therefore has been slower than elsewhere on the island, and the topography of the area is yet youthful. Toward the sea coast, the streams have cut narrow, deep, frequently cliff-walled gorges, which generally are not more than 2 miles in length. Farther inland, the valleys of the less powerful tributaries hang many hundreds of feet above the floors of these canyons. The interfluves of the inland portion of the area are ridges of moderately steep slopes; toward the coast, slightly rounded or tabular areas, generally not more than a mile in width, separate the canyons. While the surfaces of these interfluves are not remnants of the constructional surface, most of them have been lowered only slightly below this initial level.

5. Northwest of the summit plateau between Wainiha and Nualolo streams, the canyon topography resembles that of the area between the Anahola Mountains and Haupu Ridge, eastern Kauai (segment No. 2) except that the stage of erosion is not so advanced. The canyons do not exceed 3 miles in length, but are very deep, narrow alcoves, separated by narrow, extremely precipitous, sharply serrated ridges (Pl. III, *C*). The largest canyons have been cut by streams receiving their water supply from precipitation over the summit plateau. The rainfall over the region is heavier on the eastern side than on the western, hence the drainage patterns of the former area are more complicated and the canyons in general are larger. The principal streams of the eastern part have cut the mouths of the gorges to sea level; the minor streams on the eastern and practically all on the western side plunge over cliffs of various heights into the ocean (Pl. II, *A*).

The reason for the shortness of the canyons in this section is not altogether apparent. Dana (19, pp. 278, 279) and Powers (52, p. 514) consider that the straight coast line of northwestern Kauai has been caused by the down-faulting of a peripheral slice of the dome. If this be the case, the canyons have undoubtedly been truncated by this dislocation and thereby reduced in length. Positive evidence of such faulting was not obtained, though a pronounced break in the submarine contours suggests it.

The extent of the summit plateau so far to the northwest of the central part of the island must be explained in connection with this problem; the reduction of the area of the plateau apparently has taken place primarily from the northeast and southwest; the headward growth of the canyons on the northwestern side has been slow. Structural and topographic relations within the plateau area and in the sections immediately adjacent thereto are difficult to ascertain owing to climatic conditions and the abundant cover of vegetation.

Powers thinks that a second volcano was originally present on the north-

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west side of Kauai, and later was downfaulted below sea level but this is not supported by field evidence nor by a study of the submarine contours. (See pp. 52-53.)

The Emerged Wave-Cut Platform

The Hawaiian islands lie in the northern marginal belt of the coral seas where reef-building organisms exist with some difficulty and consequently do not develop luxuriant reefs. The reefs bordering the windward islands are feeble, and apparently are of late Pleistocene or Recent age. Conditions since have become so unfavorable that the reefs about Kauai and Niihau at least are now practically extinct. It seems probable that no reefs existed about any of the windward islands and possibly not about leeward islands in the earlier Pleistocene or in preceding periods, hence the islands have not been protected from wave attack by these structures to any extent; prominent abrasion features therefore are present along their shores.

For a long time after the close of the main volcanic period, Kauai remained relatively stable and was exposed to the powerful attacks of the open ocean waves. A broad platform was cut into the dome and from its inner margins great sea cliffs rose on all sides. Then diastrophic movements set in, and an intermittent tilting of the island brought the eastern half of the wave-cut plain above sea level so that the former shore line stood at an elevation of 250 to 500 feet. The western half was further submerged; the only records of its existence are from well borings located on the constructional plain of southwestern Kauai. A lava basement with overlying soil and weathered rock has been met in well borings at depths of 275 to 300 feet below sea level. This basement I believe to be the equivalent of the emerged marine platform on the eastern side of the island. On that side a large acreage was brought above sea level and the topography of the island was notably altered. Thus, at the base of the steep slopes of the eastern highland, which are the greatly battered remnants of former shore cliffs, is a rudely crescentic plain, in most places cliffed along its seaward margin (fig. 3; Pl. IV *B, C*). A number of tuff cones and residual basaltic ridges break the evenness of its surface. The platform as it emerged was a composite structure; wave-bevelled flows were exposed along its inner border; farther seaward, layers of basaltic detritus with which was intermingled a certain amount of organic material coated the rock basement. During the course of emergence, the detrital covering, except for certain boulder beaches, and smaller amounts of finer débris, was gradually swept seaward, and practically none of it now appears on the exposed portions of the plain. (See Pl. V, *B*, C.)

The platform is present only on the eastern side of the island between Hanalei Bay on the north and the mouth of the Waimea River on the south;

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at the latter place it adjoins the constructional plain of southwestern Kauai. On the northern and southern sides, the platform varies in width from 1 to 4 miles; and on the eastern side, from 1 to 8 miles. The gradient is 60 to 100 feet per mile. The great width of the eastern section is due to the extensive down faulting which took place there prior to the erosion of the platform. The floor of the engulfed area was bevelled practically to the base of the southern, western, and northern scarps. Since emergence, marine abrasion has considerably reduced the area of the platform, especially along the northern and northeastern margins where cliffs 100 to 250 feet in height have been cut; along the eastern and southern margins, these recent cliffs rarely exceed 50 feet in height.

The time required for the erosion of such a platform as that of eastern Kauai is long and requires more or less continued stability of the island. Wave action very likely was virtually uninterrupted. Though the climate may have been suitable for the growth of reef-building organisms, reef probably did not develop during the early erosional stages because of the narrowness of the platform and the abundance of detritus continually rained on to it by the actively eroding youthful streams and by the waves which were attacking the lavas along the shore line. Even after the platform increased in width, there is no evidence that reefs surmounted it until comparatively recent times. Thus the shores appear to have remained unprotected and erosion actively proceeded; continuously steepened cliffs were present and the platform was gradually widened until the tilting of the island commenced.

PLATFORM IN THE WAILUA DRAINAGE BASIN

On the eastern side of Kauai, the development of the volcanic sink has materially affected the topography of the dome. (See figs. 6, 7.) A considerable engulfment took place, but its magnitude cannot be determined owing to the subsequent changes wrought by fluviatile and marine erosion. In this section, the widest portion of the marine platform was later developed, in spite of the fact that two ridges (Nonou and Kalepa) paralleling the eastern shore must have materially reduced the force of the waves. The walls of the sink are breached, so that the southern rim (Haupu Ridge) is now separated from the main highland; a narrow gap also divides the shore ridges, and these in turn are isolated from the north and south highlands by similar depressions (fig. 3). These gaps may represent breaches made by minor faults traversing the walls of the sink or by the enlargement of former drainage lines by wave action. The Nonou-Kalepa gap appears to have been of the latter origin, since there is no evidence of faulting associated with it. The origin of the other breaches could not be determined. Thus, when the island stood at the level at which the marine platform was developed, Haupu,

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Nonou, and Kalepa ridges, together with a number of small erosion remnants, were islands in the pre-emergence sea, and the waves swept through the narrow straits between them (fig. 9).

The western and northern walls of the sink have been so greatly dissected by the numerous streams coming from the rainy highlands above that the original scarp topography and the sea cliffs at the base of the spurs have been largely obliterated. The rainfall over Haupu, Kalepa, and Nonou Ridge is comparatively light; hence these sections of the wall have been eroded by

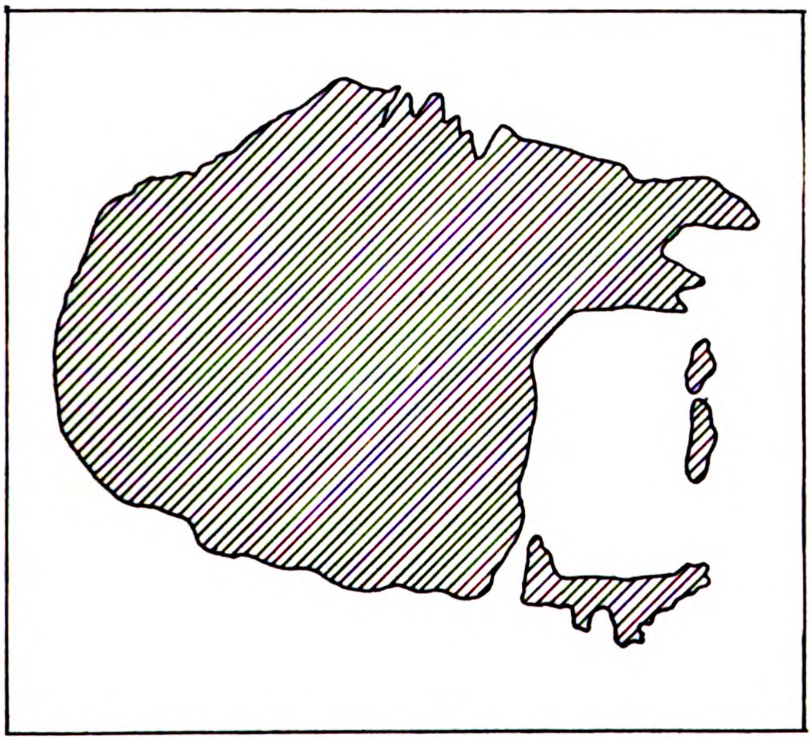

FIGURE 9.—Pre-emergence outlines of Kauai. Compare with FIGURE 3.

streams only to a slight extent. It is further probable that the steepness of the Haupu face was maintained by the sweep of waves through the Haupu-Kalepa gap.

The spurs between the valleys of the eastern (Waialeale) and northern (Makahela and Anahola) scarps exhibit less evidence of wave truncation than do those of the former northern and southern coasts of the island, apparently because of the protection afforded by the remnants of the sink wall paralleling the eastern coast and because of the dissection of any existing facets by numerous streams. The best preserved sea cliffs in this eastern section are present along the southern base of the Anahola Mountains; the wide gap between these mountains and Nonou Ridge seems to have allowed a more unbroken sweep of the waves against the ends of the spurs.

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The date of faulting which resulted in the formation of the sink cannot be determined, but, judging from the extent of the erosion of certain of the scarps, it must have been early in the postvolcanic stage. The canyons which have been incised into the northern and western walls are comparable in depth with those of the deeply eroded northern and southern sections of the island, hence they have required approximately the same time for their development. The sink was formed prior to the erosion of at least most of the marine platform, since its floor was bevelled and the interfluves of the scarp valleys were truncated by wave action when the island stood at the level at which the marine platform was cut. Considering the length of time necessary for the erosion of the marine platform and for its emergence and subsequent dissection, the engulfment must have occured well back in the Pleistocene or even in the Pliocene.

POSTEMERGENCE DISSECTION OF THE PLATFORM

During and after emergence, the highland streams, which formerly flowed into the ocean at the mouths of their canyons, were extended across the platform and incised deep, narrow gorges into the newly exposed surface (Pl. IV, *C*). The presence of broad alluvial flats in the lower mile or two miles of these valley bottoms proves that the mouths of the valleys were eroded for some distance below the present sea level (Pl. V, *A, B*). Borings in Hanapepe Canyon 1¾ miles from the coast showed alluvial sediments 60 feet below the present sea level; excavations for bridge piers near the mouth of the Wailua River were carried into alluvium for 80 feet below sea level without reaching the bottom of the deposit. The deepening of the gorges I believe took place during the periods of lowered ocean level in the Pleistocene, though no positive evidence on this point is obtainable. During and after the rise of the oceans which accompanied the retreat of the continental ice sheets, the embayed valley mouths were gradually filled with alluvial deposits which finally rose above sea level except at the mouths of the valleys where wave action has been sufficiently strong to carry the sediment seaward and thus prevent the accumulation of deltal deposits. Of course, similar topographic features may be produced by the subsidence of an island, but, on Kauai, there is no evidence that such a subsidence has taken place. The form of the upper and lower sections of the platform valleys thus is strikingly different. The upper portions are narrow, V-shaped gorges; the lower portions are steep-walled, flat-bottomed valleys in which the streams meander slightly over the alluvial deposits. The mouths of all the larger platform and highland valleys are embayed. Between the valleys, broad, tabular, practically undissected remnants of the wave-cut surface appear.

A few isolated basaltic eminences, which stood as islands in the preemergence sea, and cinder cones of comparatively recent origin constitute

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the most conspicuous positive relief features on the platform (Pl. V, *B*, *C*). The larger of these residuals are the remnants of the south and east walls of the volcanic sink (Pl. V, *B*); their elevations and dimensions are as follows:

	ELEVATION (feet)	LENGTH (miles)	WIDTH (miles)
Haupu Ridge (south wall)	2,280	8	1-2.5
Kalepa Ridge (east wall)	710	3.75	0.75
Nonou Ridge (east wall)	1,328	2	1.25

Inside the walls are two basaltic eminences, and, near the east base of Waialeale, are two other small hills of about the same size. These two hills may be either cinder cones or residuals; their surface materials are so thoroughly altered as to prevent identification. On the northern side of the platform, Kamookoa Ridge is a spur which was isolated from the highland and stood as an island in the pre-emergence sea.

ORIGIN OF PLATFORM

The evidence proving that the coastal lowlands of the eastern half of Kauai have been formed by the emergence of a marine abrasion platform rather than by the work of streams may be summarized as follows: (1) the platform slopes from the base of the highland toward the shore line rather than from a series of divides toward the various river valleys; (2) the ends of the spurs along the inner margins of the platform are frequently sharply truncated, hence they mark the line of former shore cliffs; (3) the prominent ridges paralleling the shore of eastern Kauai have been wave cliffed; (4) the surface of the platform is more even and its gradient more uniform than if the platform were the product of fluviatile erosion; (5) at various localities, minor terraces have been cut into the main structure indicating apparent interruptions in the emergence; (6) boulder beaches are present at many places along the shoreward margin of the platform.

From observations of the marine plain and the two ridges paralleling the eastern shore made during "a rapid walk" about the island, Dana (19) expressed the tentative opinion that the plain derived its lavas from the volcanic mountain which subsequently arose within the limits of an older, partially destroyed volcanic mountain of which Kalepa and Nonou ridges would be remnants. An examination of the sections exposed in the gorges of this eastern plain showed that lavas erupted from the interior of the island underlie the flows exposed in the shore ridges and also underlie the flows of Haupu and Anahola ridges which project eastward from the interior highlands on the northern and southern margins of this plain. The plain in turn has been eroded into these lavas. The flows of the ridges are therefore younger than those whose weathered products form the surface of the plain, and evidently are part of a series once continuous with that visible in the

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great Waialeale scarp to the west and in the Anahola and Haupu ridges to the north and south. The shore ridges therefore cannot be interpreted as remnants of an older volcano but are parts of the present dome isolated when the engulfment took place.

Hitchcock's opinion (40, p. 13) that the eastern plain has been constructed by eruptions from a number of subordinate cones is not supported by field observations.

PARASITIC TUFF CONES

After the emergence and partial dissection of the platform, volcanic activity developed at a number of subordinate centers, located chiefly on the marine plain; small lava flows and tuff cones were erupted (Pls. V, *C;* VI, *A*). On the southern section of the lowland, where many tuff cones appeared, much of the pre-existing topography was obscured, and elsewhere smaller sections were buried beneath these relatively recent deposits. The location of the various cones is shown on the geological map (Pl. XIII). Most of the cones stand less than 300 feet above the surrounding surface and do not exceed 1½ miles in diameter. Kilohano, however, on the eastern plain about 4 miles west of Lihue, rises about 700 feet above the plain and has a diameter of nearly 5 miles (Pl. V, *C*). The slopes of this cone are gentle, not exceeding 5 degrees on any radius. The low gradients are due in part to the presence of a considerable number of lava flows interbedded with the ejectamenta. The principal cause, however, has been the heavy rainfall over the surface of the cone, which has made for active solifluction; thus the elevation and slope have been reduced and the diameter magnified.

The eruptions at the various vents did not take place simultaneously as is shown by the difference in the degree of weathering of the ejectamenta and in the stage of dissection of the cones in sections of the island having approximately the same rainfall. The materials of the cones of the southern lowland have been lateritized at the surface, and their original characters are difficult to determine. In the Kilohana cone on eastern Kauai, the rock structures are still visible, but the ejectamenta have been thoroughly altered. Mauna Ou and Hanahanapuni, on the eastern section of the platform, which possibly may be tuff cones, have had their materials weathered beyond recognition; these eminences possibly are residuals. On the northern side, the tuffs and breccias of the Kilauea cone are comparatively fresh; those of Kamoku and Ka Loko near the northern base of the Anahola Mountains compare in stage of alteration with the materials composing the cones of southern Kauai. The ejecta of a cone (Pohakea), near the outer margin of the southern highlands, compare with Kilauea in the stage of alteration. Thus Kilauea and Pohakea appear to be the youngest cones; the relative ages of the others could not be determined.

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The outlines of the cones have been considerably modified by fluvial and marine abrasion. A few have their craters preserved, but most have been reduced to rounded domes. The extent of fluvial dissection is a factor of the rainfall over the area in which the cone is located and of the variations in

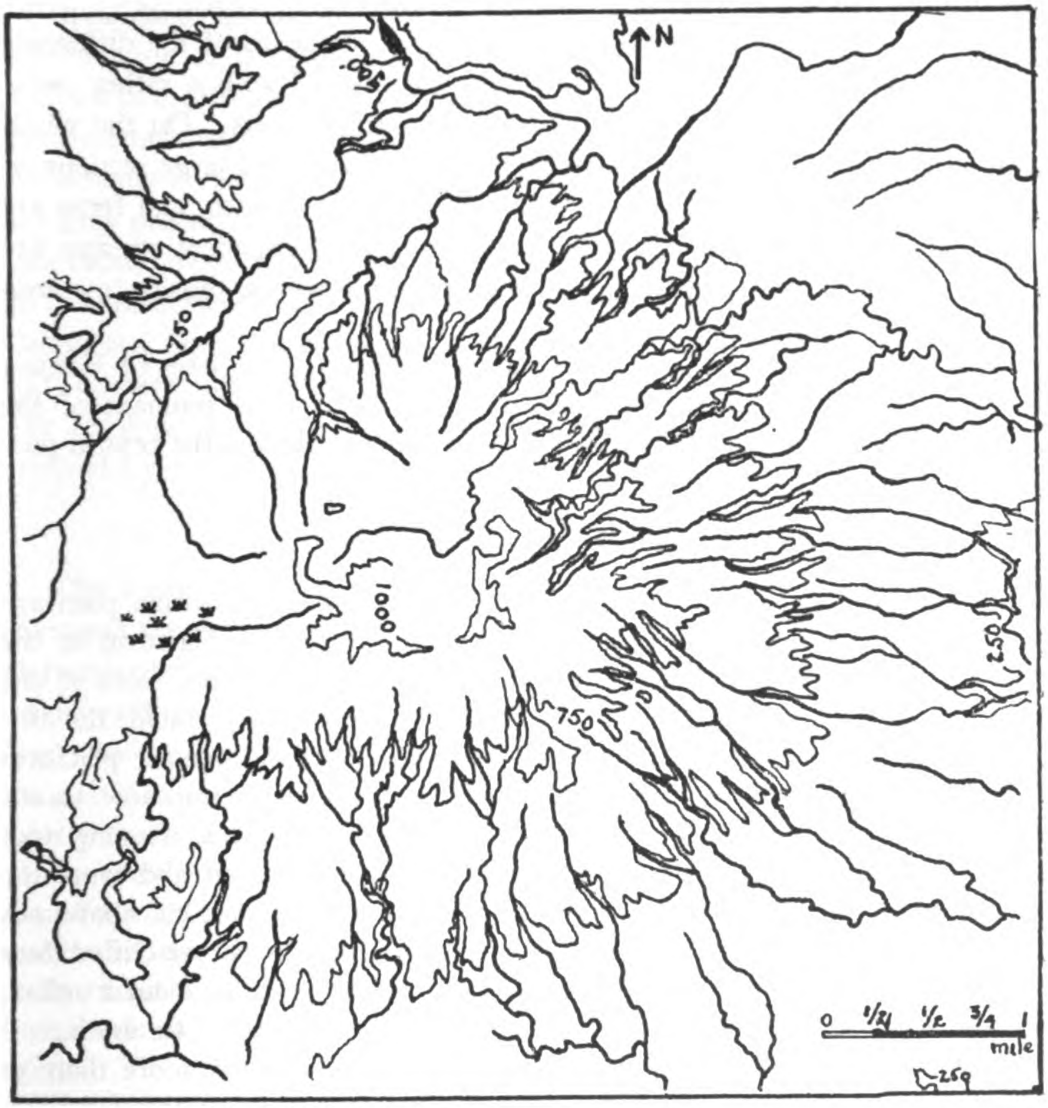

FIGURE 10.—Topographic map of Kilohano tuff cone, eastern Kauai. The asymmetric development of streams and valleys on the windward and leeward sides is illustrated. Contour interval, 250 feet.

rainfall over different parts of the cone itself. In Kilohana in particular, the stage of erosion on the windward and leeward slopes is strikingly contrasted—a reflection of sharp differences in rainfall within the narrow limits of the diameter of the cone (less than 5 miles). Unfortunately there are no quantitative measures of precipitation over various parts of the cone; at

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the single station located at the summit, the annual average is 60.15 inches. Without question, the heaviest rains fall over the windward slopes. The northern and eastern sides are cut by many deep valleys, between which are high narrow ridges. On the southern and western sides, the valleys are shallower, wider, and less numerous, and are separated by broad, conic interfluves (fig. 10). The vegetation presents further evidence of the difference in precipitation, since the windward slopes are covered with a rather dense growth of trees, ferns, grasses, and brush of various sorts. On the windward slopes, trees are widely scattered, and the divides and large sections of the valley walls are covered only with grass. The trees, brush, and ferns are largely confined to the valley bottoms. Most of the permanent streams are on the windward side. Other cones show similar features, though less conspicuously developed.

More than half of the small cone on the northern coast, west of Kilauea Bay, has been destroyed by marine abrasion. A detached remnant of the tuffs and breccias forms a small sea stack just off shore from the central portion of the cone (Pl. VI, *A*).

Southwestern Constructional Plain

Of different origin and topographically quite unlike the marine platform is the crescentic lowland (Mana Flats) which adjoins the platform at the Waimea River and extends along the southwestern and western sides of the island as far as the Barking Sands (fig. 3). As previously stated, the tilting of the island which brought the eastern half of the wave-cut platform above sea level further submerged the western part so that it now stands about 300 feet below sea level. Upon this platform grew a fringing reef which was later killed and covered by débris eroded from it and from the basaltic highland to the east. Part of this deposit now stands above sea level as a coastal plain which abuts against the stupendous, sea-cliffed face of the western highland. The greatest width of the plain is about 2 miles; nowhere does it exceed 50 feet in elevation above sea level. Its surface is comparatively flat. A coastal rampart of sand dunes, rarely more than 30 feet in height, constitutes the principal relief. Shallow, salt marshy depressions of considerable size are present at a number of places behind the coastal dune belt. Along the base of the highland is a more or less continuous steeply sloping apron of talus and alluvium which not infrequently rises a hundred or so feet above the surface of the plain. The illustrations of the Haena reef plain of northern Kauai (Pls. VI, *B*; VII, *A*; IX, *A*) are typical of the relief of the Mana flats. No valleys cross these lowlands. The flood waters which flow through the canyons of the highlands during the heavy rains are quickly absorbed in the porous soil and rarely reach the sea.

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Other Constructional Plains

Similar plains of smaller extent, formed over and behind the reef fringing northern Kauai, are found between Haena and the mouth of the Wainiha River, east and west of the Kalihiwai River, and east of the Kilauea River. In these three areas, the reef extends for some distance beyond the seaward margin of the plains; lagoons are generally present over the unburied reef surface (Pls. VI, *B*; VII, *A*, *B*; IX, *A*). Along southwestern Kauai, the limestone has been completely buried, so that the subsurface structure cannot actually be demonstrated. Its presence below the surficial deposits I think is highly probable. Another mode of accumulation of the débris in the latter area must, however, be recognized. Talus and alluvial material may have piled up in considerable thickness on the sinking platform at the base of the cliffs. Calcareous sand drifted by the strong currents running along the northern and southern sides of the island also may have found lodgment in this area. The resulting deposit gradually grew up to or near sea level, and then was exposed by the recent slight change of level which has affected the island.

COASTAL TOPOGRAPHY OF KAUAI

The shore line pattern of Kauai is relatively simple; the principal embayments are the submerged mouths of the larger streams crossing the marine platform of the eastern half of the island. These valleys appear to have been deepened during the lowered ocean levels of the Pleistocene and then to have been drowned as the sea returned to its present position. Hanalei Bay on the northern coast and Nawiliwili Harbor on the eastern coast are the principal indentations.

Before the emergence of the marine platform, the island had been strongly cliffed on all sides. The cliffs of the windward side were dissected by the numerous streams, and were further battered after the exposure of the platform ended marine erosion. These former sea cliffs are now greatly eroded high angle slopes, which show only to a limited extent the evidence of their origin. The stupendous cliffs of western Kauai, 500 to 2,000 feet high (Pls. VIII, *A*, *B*), suggest that they were cut when the prevailing wind direction in this region was different from that of today, as it may well have been during portions of the Glacial Period. A narrowing of the tropical belt as the chilling of the earth's climate progressed may have brought the stormy westerlies as far south as the latitudes of Hawaii, so that the principal wave attack for a time was along the western coast. Daly (17, p. 92) has suggested a similar shifting of the wind belts in the Atlantic during the Pleistocene to account for the giant cliffs of leeward St. Helena.

Along the northwestern and southeastern coasts of Kauai are a few sea

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stacks. Into the base of the cliffs, many sea caves have been eroded, and through narrow headlands tunnels have been cut (Pl. VIII, *B*).

The growth of the now extinct fringing coral reef upon the submerged platform of western and southwestern Kauai has protected the cliffs of that section from further wave abrasion. Between the Barking Sands and Haena on the northern coast, only a few patches of reef are present.

A notable feature of the shore pattern of Kauai is the straightness of the northwest coast; this has been explained by Dana (19, 21) and by Powers (52) as the result of down faulting. While I agree with this opinion, I am convinced that the down faulted mass was comparatively small and was not a second great dome as Dana and Powers believe (pp. 52-53). If faulting did take place in this locality, it has not been of recent date, hence the cliffs have retreated for some distance from the zone of dislocation. The width of the wave-cut bench at the base of the cliffs is not evident from the hydrographic charts. The northwestern cliffs are the highest on Kauai and compare in majesty with those on any of the other islands (Pl. VIII, *A*); they have been greatly dissected by streams, and have been recently nipped by invigorated wave attack at their base. The new cliffs average about 250 feet in height. Along the shore line are sea stacks, many great sea caves, tunnels through narrow headlands, and a few patches of extinct reef or small colonies of reef-building organisms (Pls. VI, *A, C;* VII, *B;* VIII, *B*).

The great spur of the eastern highlands which projects to the southeastern coast (Haupu Ridge) also is sharply cliffed, and has suffered recent nipping.

Since the emergence of the marine platform, sea cliffs have been cut into its shoreward margin; these vary from 250 feet in height along the northern and northeastern coast and decrease to less than 50 feet along the eastern and southern coasts (Pls. VI, *B*; VII, *C*). These cliffs in places are protected by patches of the Recent fringing reef.

The southwestern plain slopes from the base of the highlands to the shore line except where the low rampart of sand dunes is present along the coast. On the northern side, the constructional hinter-reef plains slope in similar fashion, but the fringing reef projects for some distance beyond their seaward margins (Pls. VI, *C;* VII, *A, B;* IX, *A*).

A recent slight lowering of sea level has brought narrow, wave-cut terraces 5 or 10 feet above sea level in many places; these terraces rarely exceed a hundred or so feet in width.

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DRAINAGE

DRAINAGE BASINS

According to Martin and Pierce (45, p. 36), the drainage basins of Kauai (fig. 2) are determined by three great ridges which branch off from Waialeale and Kawaikini, the central and highest points of the island:

> One of these ridges extends toward the northeast through peaks back of Kealia and along the crest of the Anahola Mountains to the sea. The other two constitute the main divide or backbone of the island, which, starting at the southeast, follows along the Haupu Ridge east of Koloa across the Koloa-Lihue Gap and then northward along the ridge east of Hanapepe basin to the summit, where it turns slightly to the northeast along the western edge of the Wainiha Basin to the sea. Another important divide leaves the main one at Kilohana, north of Alakai Swamp, and follows westward along Kaunuohua Ridge, and then southward along the western edge of Waimea Canyon to the sea. These watersheds mark out four distinct drainage areas or basins.

On the basis of this interpretation, a number of streams flowing from the summit plateau (Alakai Swanp) to the sea along the northwestern coast are included in the morphologically unrelated western drainage basin where the streams are fed by the scanty precipitation falling over the region to the west of Waimea Canyon and not from the waters of the Alakai watershed. A more natural bounding of the northern basin is as follows: The western rim of Wainiha Canyon from Waialeale to Kilohana, from the latter point westward along Kaunuohua Ridge, and then northwestward to the sea along the divide between Awaawapuhi and Nualolo valleys. The Awaawapuhi is the westernmost stream deriving its principal water supply from Kaunuohua Ridge, a part of the summit plateau.

For convenience I have named three of the drainage basins from the principal streams running through them—the northern or Hanalei Basin, the eastern or Wailua Basin, the southern or Hanapepe-Waimea Basin. As there are no dominant drainage lines in the western basin, I have applied to it the name "Mana," from the local name of the plain bordering the highland on the west. The boundaries of these basins are shown in figure 2. The Hanalei Basin receives on the average the heaviest rainfall of the island, hence its streams are the largest and most numerous. The chief drainage lines are the Wainiha, the Hanalei, and the Lumahai, while of less importance are the Waioli, the Kalihiwai, the Kilauea, and the Moloaa. The streams crossing the section of the basin west of the Wainiha River are smaller but their short canyons compare in depth with those farther to the east. The source of the drainage flowing through this basin is either in the bogs of the summit plateau or from precipitation which falls over the crests and northern slopes of the Anahola Mountains, the great ridge forming the southeastern boundary of the basin. As with all of the streams of Kauai and

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of other parts of Hawaii, underground drainage, which migrates rapidly through the porous and cavernous lavas, is an important or even a principal source of the surface streams. The main drainage lines of the eastern or Wailua Basin are the two forks of the Wailua River, which flow from the summit plateau and the adjacent mountain slopes. There are several minor streams which drain areas to the north and to the south of the Wailua system. The largest rivers of the southern basin are the Hanapepe, the Olokele, Mokihana and the Waimea. Through this area passes most of the run-off from Alakai watershed. The western, or Mana Basin, is nearly cut off from the Alakai watershed by the aberrant, southward flowing Waimea River. Because the precipitation over the basin is light, and occurs very largely during the rainy season, most of the streams have water in them only during the heavy rains. The valleys of this section therefore are sharply contrasted in form with those which have been produced by the powerful streams of the other sections of Kauai. (See fig. 8, *b*.)

In general, the courses of the streams flowing from the summit plateau are roughly radial; the north-south channel of the Waimea River, one of the principal streams of the island, is, however, an important exception. A fault line apparently has deflected the drainage lines (the Koaie, the Waialae, the Oomau, and the Mokihana), which normally should have flowed westward and southwestward from the summit plateau, and made them tributary to a master channel following the course of the dislocation. The Waimea and the Makaweli-Olokele unite near the sea. The Olokele is a southwestward flowing stream, whose course appears to have been interrupted by the Waimea fault not far from the shore line; consequently only a slight deflection of its direction has taken place (fig. 8, *a*).

FLOW OF STREAMS

The streams of Kauai are numerous and large, and, according to Martin and Pierce (44) they are more uniform in flow than are those of the other islands. Nevertheless, they are subject to considerable fluctuations in volume as the result of the marked seasonal distribution of rainfall. (See Table 7.) West of the Waimea, the streams are short, intermittent, and have few tributaries. The west rim of Waimea Canyon is the divide which separates the drainage of the Mana Basin from that flowing southwestward from the Alakai Swamp. The drainage map (fig. 3) also shows the great contrast in the complexity of the drainage patterns on the windward and the leeward sides of Kauai.

An average of approximately 80 second-feet a month of the waters of the Waimea River is diverted for irrigation purposes above the station at which the discharge measurements are made. During the dry season, the water so used is a very large proportion of the total flow of the stream.

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Diversions of the water from Hanapepe River for irrigation purposes average about 40 second-feet per month.

While in general the minimum discharge of the various streams is recorded during the dry season, there are numerous exceptions to this statement. This applies especially to the streams having their sources in the boggy summit plateau or on the adjacent ridges where the rainfall throughout the year is more evenly distributed. (See Table 2.)

TABLE 7. MONTHLY DISCHARGE OF KAUAI RIVERS (MEASURED IN SECOND-FEET)[a]

	Waimea River				Hanapepe River				Hanalei River			
	1913	1914	1915	1916	1913	1914	1915	1916	1913	1914	1915	1916
July	117.0	38.5	8.5	49.8	45.2	87.3	49.5	No	184.0	190.0	82.3	235.0
August	16.9	42.2	17.3	25.2	27.4	123.0	77.7	Record	136.0	266.0	99.8	183.0
September	52.0	294.0	46.1	14.0	18.7	317.0	71.6		116.0	1050.0	111.0	214.0
October	254.0	63.0	72.7	107.0	57.0	93.6	127.0		112.0	325.0	134.0	313.0
November	1640.0	47.5	480.0	238.0	166.0	115.0	271.0		224.0	323.0	297.0	486.0
December	37.7	382.0	347.0	534.0	27.1	206.0	126.0		12.4	610.0	162.0	636.0
January	183.0	19.5	1640.0	367.0	22.1	17.5	196.0		112.0	140.0	275.0	535.0
February	81.1	76.4	209.0	299.0	13.8	24.8	93.1		91.0	153.0	84.6	164.0
March	232.0	1.78	320.0	514.0	19.8	15.9	114.0		137.0	93.3	158.0	956.0
April	905.0	179.0	105.0	133.0	30.8	110.0	34.3		237.0	424.0	52.3	210.0
May	62.5	17.5	184.0	183.0	92.4	22.4	96.0		320.0	203.0	136.0	441.0
June	39.0	56.8	50.4	91.6	109.0	56.5	80.9		330.0	266.0	88.7	398.0
Yearly	229.0	101.0	291.0	214.0	52.5	99.2	112.0	....	176.0	337.0	322.0	401.0

[a] Data compiled by Grover (26, 27), Grover and Larrison (28).

SURFACE FLOW AND UNDERGROUND DRAINAGE

In Hawaii, the most casual observations show that the amounts of run-off and of water penetrating below the surface vary greatly at different times in the same area and vary permanently over different sections of the same mountain. This is notably so on the higher, better watered domes of the group.

On Kauai, no quantitative measurements of the relation between run-off, evaporation, and accessions to the groundwater supply have been made, but certain general facts are perhaps worthy of brief consideration.

1. On the mountains of Kauai, the windward slopes receive much heavier precipitation than do the leeward, (fig. 2). Because of the more abundant run-off and groundwater, the windward rivers are larger, more permanent, and less subject to great fluctuations in volume.

2. The storms vary greatly in intensity; during the rainy season, the fall of water is extremely heavy, so that very high maxima are commonly measured for brief periods of time. The precipitation over the whole island is in the form of rain. It is evident that the accessions to the groundwater

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supply are much more per unit of water falling during the light rains of the drier months than during the torrential rains.

3. According to existing records, Kauai is the most heavily watered of the Hawaiian islands; the greatest annual average measured elsewhere in Hawaii is 350 on the summit of West Maui. The areas on Kauai over which average annual rainfall of 80 inches or more fall are as follows:

INCHES	SQUARE MILES (approximate)	INCHES	SQUARE MILES (approximate)
450	10	250	50
400	10	200	55
350	15	150	110
300	30	100	120
		Under 80	135

Over the Kauai lowlands, most of the rain falls during the winter months; on the highland slopes, it is much more uniformly distributed throughout the year.

4. The relief of most parts of Kauai is extremely rugged, and the slopes are steep. The elevated marine platform, the various constructional plains, and the summit plateau have gentle slopes. The constructional plains have the least diverse surfaces and the lowest slopes.

5. Except in the rainy sections of the island, the soils are porous and allow the ready penetration of groundwaters. Even through the more compacted clayey soils of the heavily watered upland, great quantities seep. The most porous surficial materials are the moderately coarse grained calcareous and basaltic sands of the constructional lowlands, and through these even the torrential flow from the highland valleys quickly sinks. Below the soil cover and the zones of deeply weathered rocks, the fresher lavas are abundantly supplied with openings; vesicles; vesicular, scoriaceous, and brecciated flow tops; joints of all sizes; cavernous spaces between the various layers of many flows and between the flows themselves; and faults. Even though much compacting has taken place from the crushing weight of the overlying lavas, the rocks exposed farthest below the surface have innumerable channels through which waters can penetrate. A few extremely dense flows and many of the sills and narrow dikes are relatively impervious.

6. Except in the rainiest sections, the saturation of the soils and immediately underlying rocks varies with the seasons. During the rainy months, the water table is close to or at the surface, but falls rather rapidly during the drier portion of the year. In the uplands, the more or less continuous fall of rain keeps the soils well saturated. Farther below the surface, certain of the porous zones evidently carry nearly their maximum quantity of water, but most are far from saturated.

7. The lavas dip seaward from the central part of the island at angles generally less than 10°. This quaquaversal structure, combined with the

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high porosity of the rocks, makes for the active migration of the groundwater solutions. Downward penetration and migration along the dip are rapid. The meteoric supply works its way for some distance below sea level, and has sufficient head to force back the ocean waters which otherwise would occupy the openings. Wells drilled far enough from the sea and reaching zones in which the flow of water is rapid remain fresh. Migration of groundwaters and the abundance of the supply are apparent along most of the mountain slopes; many streams are fed from spring lines and not from the surface flow. Not infrequently these springs are located hundreds of feet below the crests of the interfluves. According to Mr. L. D. Larsen, Manager of the Kilauea Plantation, a considerable part of the drainage from the northern slopes of the Anahola Range comes from springs which emerge at an elevation of about 1100 feet, which is in places over a thousand feet below the top of the mountains.

8. The vegetation cover in the rainy sections plays an important part in checking the rate of run-off from the steep slopes. Over the lowlands and the leeward sections the plant cover is relatively scanty.

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KAUAI-NIIHAU VOLCANO

A study of the hydrographic charts of Kauai and Niihau shows that these two islands are the summits of a compound volcano, one of the mountains in the Hawaiian range, which extends from an unnamed shoal 280 miles west-northwest of Ocean Island 1900 miles southeastward to the island of Hawaii. On the basis of existing data, the submarine contours cannot be drawn with sufficient detail to indicate whether or not submerged major eruptive centers exist, though there are certain indications that such is the case. As on Oahu, Maui, and Molokai, the western member (Niihau) of the pair of domes first became extinct. Whether Kauai and Niihau ever were united above sea level cannot be determined. Since downfaulting has caused the disappearance of the eastern half of Niihau, the islands were once more nearly contiguous than at present, but I do not think that exposed connections ever existed between them. The original relations probably were similar to those now existing between Maui, Molokai, Lanai, and Kahoolawe—these four sections of a single huge volcano are separated from each other by narrow channels of relatively shallow depths.

The submarine connection between Kauai and Niihau is shown by map and cross section (Pl. X; figs. 11, 12). The contours have been plotted from

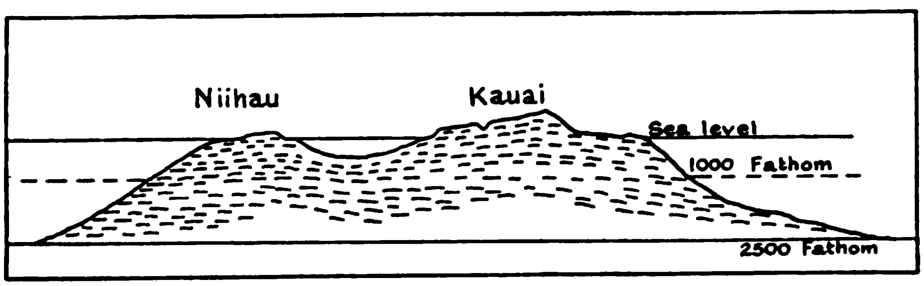

FIGURE 11.—Cross-section of the Kauai-Niihau volcano. Horizontal scale: 1: 1,950,000; vertical scale: 1/10 inch=5000 feet.

data given on Hydrographic Chart 4117, published by the United States Coast and Geodetic Survey, and extend to depths of 1000 fathoms; beyond this limit, only a few scattered soundings have been made. While the floor of the ocean about the mountain averages nearly 2,500 fathoms in depth, it is probable that the form of the volcano does not change greatly below the 1000-fathom line. The soundings at lesser depths are too few to permit an exact delineation of the submarine relief, but the general relations are evident. Soundings off shores of Niihau are fewer than off Kauai, hence the contouring of the submerged slopes of that mountain is incomplete, especially on the southern side. It is impossible, for example, to determine the relation of

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Niihau to the small tuff cone, Kaula, which lies 19 miles to the southwest. Kaula certainly cannot be a parasitic tuff cone on the submerged flank of Niihau, since, if the slope of that dome be more or less uniform, Kaula would rise from a depth of over 2,000 fathoms. It is reasonable to postulate that the cone rises from a third dome whose presence has not been recognized because of the scarcity of the soundings. If the summit of this dome approached fairly close to sea level, the height and mass of Kaula would not be very different from similar dimensions of other cones in the archipelago.

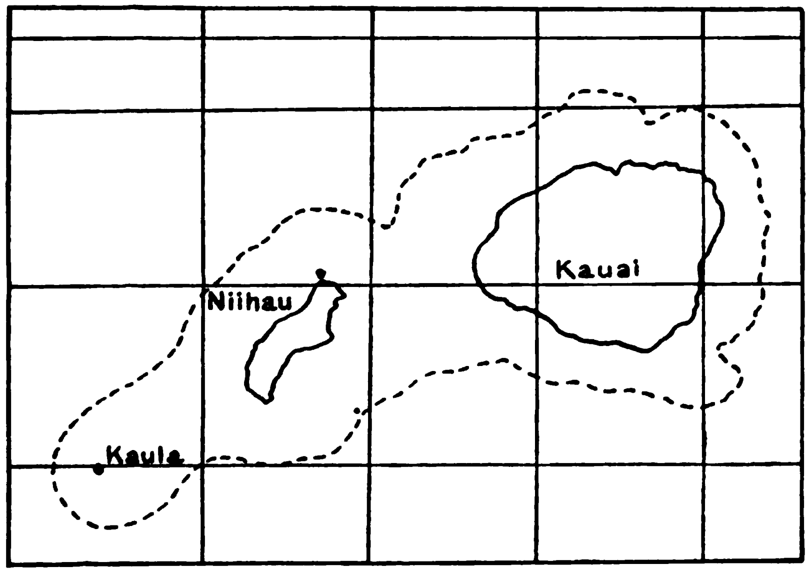

FIGURE 12.—Ground plan of the Kauai-Niihau volcano at a depth of 1,000 fathoms. The submarine connection of the submerged platform upon which the tuff cone, Kaula, is imposed is shown by the dotted line. Scale: 1: 1,800,000.

Kaula has been described in some detail by Palmer (48, pp. 6-10), and a survey of the island and surrounding waters was made recently by Captain C. L. Garner of the U. S. Coast and Geodetic Survey. The survey shows that the tuff cone surmounts the eastern edge of a submarine platform which has an area of approximately 30 square miles. The depth of water over the platform varies from 27 to 53 fathoms, while away from its margins, the depths exceed 200 fathoms. At a point about 3 miles northwest of Kaula, a rocky pinnacle extends to within 38 feet of the ocean surface. This survey confirms the view that Kaula was imposed upon a submerged dome. This mountain very likely once rose above sea level, and has long since been destroyed by erosion. Palmer has found that a reef grew up on the submerged platform, and that through this the materials of the cone were erupted. The mountain represented by the submerged platform undoubtedly is a part of the Kauai-Niihau volcano.

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About one-half mile north of Niihau is another tuff cone, Lehua (elevation 738 feet), which has been erupted on the northern slope of the dome.

From a brief reconnaissance on Kauai, Powers (52) concluded that the island

> . . . was originally a volcanic doublet, the western half of which has disappeared. . . . Dana was the first to notice that the flows truncated in the Na Pali cliffs dip toward Waialeale; but he supposed that Niihau represented the missing volcano, moved southward. . . . Niihau is but a remnant of the original volcano, the center of which was east of the present island . . . . The northeastern part (of Niihau) is bounded by a fault-scarp, along which the greater part of the original island has subsided; but this scarp is not a continuation of that at Na Pali.

I have not been able to find in Dana's papers (19, 20), a statement that the lavas of the northwestern section of the island dip toward the center at Waileale. Dana suggests that Kauai was originally a doublet island through which a great fracture zone developed having a trend approximately at right angles to the fissure system over which the archipelago has been built. Along this transverse zone, both vertical and horizontal movement took place. The vertical movement caused the disappearance below the sea of most of the "lost" dome; the horizontal caused the transference to its present position of the residual mass (Niihau).

I have made a detailed examination of the structural relations and of the sections exposed in the cliffs in a number of the canyons which opened to the sea along the Na Pali coast between Wainiha and Kolalau; in Honopu, Nualolo, and Milolii canyons to the west of Kolalau; and in certain of the smaller gorges opening onto the coastal lowland near the Barking Sands. In each of these canyons, except for unimportant local variations, the flows dip seaward at angles generally less than 10°, and thus correspond in their relations to those of the rest of Kauai. No general dips toward the central part of the island were noted. As Plate X indicates, the submarine contours do not show a great scarp off northwestern Kauai which could be interpreted as a zone of faulting along which a second dome had disappeared. The view held by Dana and Powers that Kauai originally was a doublet island is impossible of acceptance; the island always has been a single dome. Niihau is the remnant of a larger volcano, the eastern portion of which apparently has disappeared as the result of engulfment. The present cliffed face does not represent the line along which the dislocation took place, since the powerful wave attack along the coast has undoubtedly caused a considerable retreat of the scarp. The present cliffs of eastern Niihau therefore are a fault line scarp and not a fault scarp. The extent of the retreat from the fault zone cannot be definitely ascertained because of the few soundings which have been off eastern Niihau. Two depths of 40 and 42 fathoms respectively, 1½ to 2 miles off the southern end of the island indicate the presence of a

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submerged bench. A sharp change of slope is shown by soundings 250 to 400 fathoms within a half mile of the localities first mentioned. This bench may be continuous along eastern Niihau, but no depths have been measured close enough to the cliffed coast to prove its presence. The break in slope may represent the position of the fault scarp, and the bench the distance to which the cliffs have retreated under wave attack subsequent to the dislocation.

My field studies have confirmed Powers' observation that the lavas exposed in the cliffs of eastern Niihau have no relation to those of northwestern Kauai; hence Niihau does not represent a fragment of Kauai.

Washington's statement (59, p. 337) that Niihau is tectonically related to the leeward Hawaiian islands is out of accord with the evidence at hand. Niihau is separated from Nihoa, nearest of the leeward islands, by 140 miles of ocean averaging 1,500 to 1,800 fathoms in depth. In geology, morphology, and structure, Niihau is related to the younger, windward section of the archipelago. Its close association with Kauai cannot be disputed.

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IGNEOUS GEOLOGY OF KAUAI

STRUCTURE OF KAUAI DOME

The main igneous complex of Kauai is composed for the most part of thin, trappean or porphyritic flows of basalt and pyroxene andesite which dip seaward at angles of less than 10° from a principal eruptive area located near the center of the island. The great mass of the lavas has come from vents within the jungle-covered portions of the rainy highlands, hence their sources cannot be located; other flows have been erupted from central vents or from fissures located at various places along temporary constructional surfaces. Many of the feeders of this second group of flows are visible in the sections exposed in the great canyons of the drier parts of the island. The flows average less than 20 feet in thickness; very few exceed 50 feet. They gradually thicken toward their source. Their lengths and widths are difficult to measure because of the great amount of weathering and erosion which has taken place and because of the heavy cover of vegetation which hides much of their upstream sections. The lava is principally of the clinker (aa) type; the proportion of clinker to ropy (pahoehoe) surfaced flows is about three to one. Relatively few flows of blocky lava were observed.

Interbedded with the flows are occasional pyroclastic deposits but the volume of these is so small that the form and structure of the dome have not been affected to any extent by their presence. The deposits doubtless represent tuff and cinder cones erupted on temporary constructional surfaces which later were buried by lava floods. So far as can be determined, all of the ejecta are of basaltic or andesitic composition.

The main complex is cut by great numbers of trappean and porphyritic dikes which for the most part radiate from the central portion of the dome; certain groups, however, are associated with minor eruptive centers. The relations of the dikes are splendidly shown in the lower portions of the canyon walls and in the sea cliffs, but are completely obscured in the rainy highlands because of the deep regolith and the heavy cover of vegetation. The dikes rarely exceed 10 feet in width, and generally have been formed by single injections; a few multiple and composite dikes were observed. Great numbers of sills also are present; most of them are not more than 8 or 10 feet thick, but occasionally sill-like or laccolithic bodies up to 250 feet thick were found. Magnificent columnar jointing has developed in many of the dikes and sills and in some flows (Pl. II, *B*). Variations in the normal injection relations in both types of intrusives were noted; the dikes not infrequently are concordant or nearly so at one or more places in their courses and then assume their usual positions. The sills in like manner transgress from one horizon to another. In a number of places, the dikes

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are clearly flow feeders. A few, irregular, stock-like or chonolithic bodies were observed, but were so inaccessible that their relations could not be studied in detail. Boulders of coarsely granular rock found along a number of the stream beds indicate the presence of course-grained parent intrusives, but none was discovered. The location of some of the boulders suggests that they may have come from lava tube fillings or from sill-like injections similar to the Uwekahuna mass at Kilauea (57), though the texture of the rocks is distinctly coarser than that from Uwekahuna. These boulders do not appear to have been derived from the normal sills or dikes, neither are they to be associated with the pyroclastic deposits.

LAST VOLCANIC EPISODE

After the erosion of the dome practically to its present form, a later period of volcanic activity developed at a number of subordinate centers, most of which were located on the marine platform of the eastern half of the island; a few vents were opened in the highlands. Over a score of tuff cones and small lava flows were erupted. Along the southern lowlands, where activity was most intense, the topography of the platform has been considerably changed by the development of numerous tuff cones; some of these show distinct linear arrangement probably along fissures. The most extensive outwellings of lava came from fissures located near the base of Haupu Ridge, southeastern Kauai. This volcanic episode occurred in late Pleistocene or early Recent time, but sufficiently long ago to allow the deep weathering of the pyroclastics and the extensive erosion of most of the cones. The cones vary considerably in age, since, in areas of about the same rainfall, the degree of weathering and erosion is quite different. The position of the various cones is shown in Plate XIII.

PRINCIPAL ERUPTIVE CENTER

On Kauai, the principal eruptive area is hidden below the jungle tapestry of the rainy highlands. In such sections as are available, distinct flow structure can be traced on all sides close to the center of the island, but there is a considerable area in which no definite field data can be secured. In the central part, the flows are nearly horizontal or have an outward dip of not more than 3°; farther seaward the dip increases to 8° or 10°. The eruptive center or area thus appears to have been located in the region of horizontal or low dipping flows, but its nature could not be determined. If a sink were originally present, it has since disappeared; possibly it may have been largely filled with pyroclastics of which there are considerable quantities in the central part of Kauai. Fissure eruptions were numerous as the abundant dikes testify, but evidence was not secured to determine whether the island is of the Ascenion-St. Helena or of the Mauna Loa-Kilauea type.

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No great central monolith, such as Dana (20) described from Tahiti is present on Kauai, since structureless rocks are not to be found in any of the sections visible in the upper courses of the canyons, nor are coarsely granular rocks of types which would form such a body present in the stream beds. If a central vent existed, the throat must have been narrow for some distance below the surface, and the lava which solidified therein relatively fine-grained.

IGNEOUS STRATIGRAPHY

At only one horizon in the exposed portion of the main igneous complex of Kauai is there evidence of a notable break in the eruptive sequence. In several of the canyons of western Kauai at elevations of about 500 feet, beds of course volcanic conglomerate overlie an erosion surface which has been cut into the lavas. The best exposures are in the bottom of Waimea Canyon, between the Waialae and Poomau streams. Unfortunately, the exposures are limited and little can be seen of the underlying erosion surface. The deposits are of sedimentary rather than of igneous origin, but whether they be marine or fluvial could not be determined. In the other canyons, this conglomerate was not observed, but conditions of erosion, the depth of rock weathering, and the heavy cover of vegetation may have concealed it. Whether this apparent break represents an important erosion interval is difficult to say, but I am inclined to believe that it does, and shall use the horizon to separate an older and a younger series of lavas composing the main complex. To the three groups of rocks, I shall apply the following names: Lower Kauai lavas, Waimea conglomerate, and Upper Kauai lavas.

Most of the older Kauai lavas were erupted below sea level, and the visible exposures are limited; the rock types are similar to those composing the upper series. The later series includes all of the intrusive and extrusive rocks erupted after the deposition of the Waimea conglomerate up to the close of the last principal eruptive cycle. This series apparently was not broken by any long erosion interval. Most of the flows have remarkably fresh surfaces, though a considerable amount of weathering has been accomplished by underground waters. Occasionally sufficient time elapsed between eruptions for the development of thin lateritic soils, but little erosion seems to have taken place. The lateritized zones are not continuous horizontally for any great distance, hence they are not of sufficient importance to be recognized as breaks in the stratigraphic column. The maximum thickness of the later Kauai series is about 4,000 feet. The thickness of the Waimea conglomerate probably does not exceed 75 or 100 feet, while that of the lower Kauai lavas cannot be determined.

After the close of the late Kauai volcanicity, minor eruptions took place at various centers, as they did on all of the Hawaiian domes. Most of these

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cones have been almost completely destroyed by erosion, and the pyroclastics remaining have been very deeply weathered.

The last phase of the eruptive cycle developed long after the sealing of the principal eruptive areas or vents and after most of the present erosional topography had been evolved. Many fissures and vents were opened on the emerged marine platform and a few in the highlands. More than a score of tuff cones were erupted, and a number of small lava flows buried various areas of the older lateritized rocks below. This activity developed after the emergence and erosion of the platform as is shown by the burial of parts of valleys which had been cut after the emergence. The eruptions took place in late Pleistocene or early Recent times, but were not contemporaneous. The pyroclastics have been weathered to different degrees, even in areas where there is little difference in the rainfall; some of them have been altered almost beyond recognition. Since most of these late outbursts took place in the Koloa District, southern Kauai, I have called the episode by that name.

The principal events of the igneous history of Kauai therefore are:

1. Eruption of the older Kauai lavas.

2. Erosion interval and deposition of the Waimea conglomerate. Whether this was a time of complete cessation of volcanic activity is not known.

3. Eruption of the younger Kauai lavas.

4. Erosion interval and emergence of marine platform. Minor eruptions appear to have continued from subordinate vents.

5. The late Koloa volcanic episode. Lavas and pyroclastics erupted from vents located mainly on the emerged marine platform.

IGNEOUS ROCKS

PREVIOUS INVESTIGATIONS

Details of the petrography of the Kauai lavas are even more meager than observations regarding the general geology of the island. Dana (19) noted the predominance of olivine basalt in the main igneous complex and the presence of a much later series of fragmental deposits and lava flows near Koloa on the southeastern coast which he described in some detail. In flows exposed in Hanapepe Canyon, Dana observed "crystals" of olivine more than one inch in length. Later studies have shown these to be small dunite xenoliths and not phenocrystic individuals of olivine. In a collection made by the zoologist, Schauinsland, in 1898, Kauai lavas are represented by three specimens from a locality given as Tipukai, which undoubtedly is Kipukai on the southeastern shore. According to descriptions later published by Möhle (47, p. 89), these rocks are porphyritic and aphanitic olivine basalts. Lindgren (43, p. 15) mentions a "coarse-grained olivine diabase" which was said to have come from "a large boulder in one of the principal streams of Kauai."

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This rock was studied in the field and described by Cross, who collected from a number of localities on Kauai. Cross (7, p. 9) described two olivine basalts from Olokele Canyon; plagioclase basalt from a flow of the late volcanic episode near Kilauea; limburgite, containing inclusions of harzburgite and dunite, from boulders in the bed of Hanapepe Canyon near the falls; oligoclase gabbro (kauaiite), the coarsely granular "diabase" of Lindgren, from boulders of unknown origin near the mouth of Waialae River; and nephelite-melilite basalt, incorrectly associated with a late cinder cone near Kilauea on the north shore of the island. Analyses of the two olivine basalts, the oligoclase gabbro, and the nephelite-melilite basalt are given. Cross's report contains the only detailed descriptions of igneous rocks from Kauai.

Powers (53) made extensive collections from both Kauai and Niihau, but his report pays scant attention to the microscopy of the lavas. He emphasizes the abundance of olivine basalts and notes the presence of the late series of lavas and pyroclastics (the Koloa series). He describes briefly dunite nodules in a flow of picritic or limburgitic basalt near Puu Kahoaea, west of Lihue, and records other localities where similar inclusions are present. The mineral composition of a gabbro xenolith from a flow near the falls in Hanalei Canyon also is given, Hinds (34) has published an account of the melilite and nephelite basalts from Kauai and Niihau.

OLIVINE BASALTS

As shown in an earlier paper (37, pp. 298-310) the dominant Kauai lavas, both of the main complex and of the much later Koloa series, are olivine basalts, which apparently compose about 85 per cent of the total visible mass of the island. These rocks range in color from ash-gray, medium-gray, greenish-gray to dark-gray, geenish-black, brownish-black, or black. Texturally, most of the rocks are porphyritic, though many of the thin sills, narrow dikes, and a few flows are composed of aphanitic lavas. The most noteworthy feature of the olivine basalts is the size and abundance of the olivine phenocrysts which are visible to the eye or under a hand lens in at least 90 per cent of the rock bodies. Tabular feldspars are nearly or quite as abundant as the olivines, especially in the more salic varieties. Magnetite and augite, the other principal constituents, are visible in relatively few hand specimens. In structure, there are all possible gradations from highly scoriaceous or vesicular lavas to dense rocks, in which gas cavities, if present at all, are of microscopic size. While a few amygdaloidal flows are present, complete filling of the vesicles is rare. In many flows, the cavity walls are coated with zeolites, opal, quartz, or calcite. Calcite is being deposited in vesicles and fissures along the sea coast, and is found as linings or fillings of vesicles in flows and beach boulders along old shore lines. Flow structure

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is rare in the olivine basalts. The microscope shows that most of the rocks are holocrystalline except for occasional globules of brownish, isotropic, or partially devitrified glass. The abundance of glass naturally increases toward the top and base of the flows, though in most specimens examined, the texture is holocrystalline a very few inches below the surface. In a few thin sections, more or less continuous areas of glass or of its partially or wholly devitrified equivalent form an essential part of the groundmass.

In composition, the olivine basalts vary from types in which olivine is not conspicuous and plagioclase equals or exceeds augite in amount to pyroxenic facies in which olivine is abundant and plagioclase is distinctly subordinate. The end types are olivine andesite at the salic pole and ultra femic and picritic basalts at the femic pole.

Megascopically, most of the olivine basalts of Kauai can be separated into four groups which have proved of service for field classification:

1. Coarse grained chrysophyres: light to dark-gray lavas in which large, yellowish-green to deep, bottle-green olivines are common. Plagioclase tablets generally are abundant and many of them equal the olivines in size.

2. Fine grained chrysophyres: dense, dark colored lavas in which small, dark-green olivines are abundant. Feldspars are not so commonly phenocrystic as in the rocks of the first group. Both coarse and fine grained chrysophyres are found as flows, dikes, and sills.

3. Highly vesicular olivine basalts possessing saccharoidal texture: dark-colored, moderately coarse grained rocks with abundant phenocrysts of olivine and plagioclase. These are exclusively flow rocks.

4. Trappean basalts: dense, dark-colored lavas in which minute olivines may be visible under a hand lens. The thin sills, narrow dikes, and occasional flow rocks belong to this group.

The coarse and fine grained chrysophyres appear to compose 75 to 80 per cent of the olivine basalts of Kauai, and the proportion of the coarse to fine grained types is about 1 to 2. The highly vesicular, saccharoidal lavas are next in importance. The volume of the trappean rocks is small.

Other Types of Lavas

Andesitic basalts, containing less than 5 per cent of olivine and higher proportions of more alkalic labradorite than the normal olivine basalts, are next in abundance, but their total mass is relatively small. Pyroxene andesites (olivine-poor or olivine-free) are fairly common and are the most salic lavas so far found on Kauai. The andesitic basalts and the pyroxene andesites closely resemble the olivine basalts in megascopic appearance, except for the paucity of the olivine phenocrysts. A number of these more salic flows show well developed flow structure. Trachytic and other types of

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highly alkalic lavas, such as have been found on Hawaii, Maui, and Oahu, have not been recorded from Kauai. In addition to the types already mentioned, melilite basalt, nephelite-melilite basalt, nephelite basalt, analcite basalt, picrite basalt, picrite, diabase, and limburgite are represented in my collection. The nephelite, analcite, and the melilite basalts with one exception were obtained from the main igneous complex (34). A single melilitic flow, belonging to the late Koloa volcanic episode, was found west of Koloa on the south shore of Kauai. The melilite basalt described by Cross (7) is from the main complex and is not associated with a tuff cone of Koloa age as that writer believed. No hornblende-bearing or quartz-bearing rocks were found on the island.

Possible Plutonic Rocks

The presence of coarsely granular rocks on Kauai has been noted elsewhere (33, p. 22). Many of the flows contain gabbroid, pyroxenitic, and peridotitic xenoliths. Other coarse-grained rocks were found in pyroclastic deposits and as stream boulders whose sources were not ascertained. The list of petrographic types includes oligoclase diorite, oligoclase gabbro, olivine gabbro, olivine-free gabbro, troctolite, harzburgite, pyroxenite, and dunite. Whether these rocks were derived from deep-seated intrusions or from coarsely granular hypabyssal bodies cannot be determined in most specimens.

Recurrence of Petrographic Types

Of the various types of lavas, most were found to recur at various horizons in the Kauai dome, so that no sort of density stratification appears to exist. The nephelite basalts were found below elevations of 1,500 feet above sea level, but it is entirely probable that flows of this type are present at higher levels. Melilitic rocks were found from sea level nearly to the top of the dome. No difference appears to exist between the rocks of the older and younger Kauai series. The lavas of the late Koloa episode in general are more femic than those of the earlier volcanic periods, while highly plagioclasic types are distinctly less common. Highly differentiated facies, such as the melilite, nephelite, and analcite basalts, the limburgites, and the picrites were developed at various times during the principal volcanism, and are not confined to the late episode as Cross and Powers suggested.

Chemical Composition

Unfortunately, few analyses of lavas from Kauai are available; from Niihau several have been recently published by Washington and Keyes (59, p. 339). In Table 8, additional analyses are given.

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TABLE 8. ANALYSES OF HAWAIIAN LAVAS

	1	2	3	4	5	6
SiO_2	48.99	45.48	47.24	40.56	48.69	49.73
Al_2O_3	13.73	11.87	12.80	8.81	14.00	13.71
Fe_2O_3	1.60	1.98	1.79	5.98	5.03	2.92
FeO	10.46	9.87	10.17	8.23	8.01	8.64
MgO	13.53	13.28	13.42	16.33	7.12	8.27
CaO	7.34	10.97	9.16	11.77	9.00	9.10
Na_2O	1.62	2.21	1.92	3.13	3.55	3.16
K_2O	0.27	0.77	0.52	1.19	1.24	1.02
H_2O+	0.27	0.74	0.50	0.27	......	......
H_2O-	0.10	0.23	0.17	0.06	......	......
TiO_2	1.73	1.90	1.82	2.73	2.29	2.84
P_2O_5	0.13	0.25	0.19	0.82	0.49	0.48
MnO	0.20	0.15	0.18	0.15	0.41	0.13
	100.38	99.94	100.24	100.03	99.83	100.00

1. Coarse-grained chrysophyre (Field group 1). Olokele Canyon, Kauai. W. T. Schaller analyst. Cross (7, p. 11).
2. Fine-grained chrysophyre (Field group 2). Olokele Canyon, Kauai. W. F. Hillebrand, analyst. Cross (7, p. 11).
3. Average of Nos. 1 and 2.
4. Picrite-basalt. Lihue, Kauai. H. S. Washington, analyst. Washington (58, vol. 12, p. 344).
5. Average of 43 analyses of lavas from the Hawaiian islands. Cross (7, p. 87).
6. Average of 56 analyses of the lavas of the island of Hawaii. Washington (58, vol. 6, p. 361)

It is impossible to estimate the average composition of the Kauai lavas from data now at hand, but because the olivine basalts of Field groups 1 and 2 are the dominant lavas of the island, I think that the average of the two analyses given in column 3, Table 8 represents a fair approximation of the olivine basalts. These rocks compose at least 85 per cent of the mass of the dome.

As Niihau is a part of the great, compound Kauai-Niihau volcano and its lavas are petrographically rather similar to those of Kauai, the analyses recently published by Washington and Keyes (59, p. 339) are presented. (See Table 9.)

Composition of Weathered Rocks and Soils

No weathered rocks from Kauai have been analyzed, but a few analyses of similar weathered rocks from Oahu have been published by Lyons (44). From a paper on the weathering of Hawaiian lavas (37) the following paragraphs have been taken.

As previously stated, the weathering of the Kauai lavas has taken place under a great variety of climatic conditions resulting from marked differences in rainfall over various portions of the island.

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The weathering of the lavas has been accomplished primarily by chemical agents. Mechanical disintegration is important along the sea coasts, in stream channels, and on steep mountain slopes where landsliding and creep proceed at maximum rates, but the areas involved are limited. The effect of frost at higher elevations probably is of little consequence, since freezing temperatures develop only occasionally and the rocks in the highlands have been weathered chemically to very considerable depths below the surface. The chemical alteration of the lavas has taken place under climates ranging from rather arid to extremely humid; the mineralogical and chemical changes in the lavas vary with the climate of different sections of the island.

Unfortunately all of the analyses of Kauai soils and subsoils are of samples which have been taken from elevations of 1,000 feet or less, hence there are no representatives from the extensive, most heavily watered sections of the island.

The soils and subsoils of Kauai in the main are residual, having been derived from the decomposition in situ of flows and volcanic ejectamenta. Along the southern low-

TABLE 9. ANALYSES OF LAVAS OF NIIHAU

	1	2	3	4
SiO_2	49.73	46.44	46.86	46.36
Al_2O_3	14.56	16.21	14.78	14.77
Fe_2O_3	3.60	1.98	1.78	2.13
FeO	8.55	7.85	9.85	8.82
MgO	6.89	9.45	9.93	12.42
CaO	9.66	11.21	10.98	10.84
Na_2O	2.25	2.52	2.88	2.16
K_2O	0.62	.48	.40	.53
H_2O+	1.24	.54	.13	.57
H_2O-	.71	.10	.16	.12
TiO_2	2.21	2.11	1.67	1.31
ZrO_2	n.d.	......	n.d.	n.d.
P_2O_5	.22	.21	.20	.19
SO_3	n.d.	.11	n.d.	n.d.
Cr_2O_3	n.d.	.07	n.d.	n.d.
MnO	.11	.21	.15	.14
BaO	n.d.	n.d.	n.d.	n.d.
	100.35	99.49	99.79	100.36

1. Andesine basalt, Keanahuhi Valley, Kaeo Cone, Niihau. M. G. Keyes, analyst.
2. Olivine labradorite basalt. Kalaalaau Valley, Niihau. M. G. Keyes, analyst.
3. Olivine labradorite basalt, Puuwai Cone, Niihau. M. G. Keyes, analyst.
4. Olivine labradorite basalt. Nonopapa Landing, Niihau. M. G. Keyes, analyst.

lands, and to a less extent along the northern and eastern lowlands, fragmental volcanic deposits, erupted from local vents, have been superposed on the weathered lavas. These deposits, so far as can be determind from microscopic examination, are composed of fragments of the basaltic types previously described. Along the coast, detritus derived from the disintegration of local fringing reefs, is added to the basaltic débris. In the lower portions of the submerged river valleys on the lowlands of eastern Kauai, alluvial deposits, composed of basaltic detritus, have been formed, and represent the largest areas of transported soils. At the mouths of the rivers, reef limestone sand has been added to the basaltic alluvium. At the bases of steep mountain slopes are limited accumulations of material brought down by landsliding and creep.

The soils and sub-soils of the lowlands and drier mountain slopes of Kauai and the other Hawaiian islands are essentially residual laterites which vary widely in composition. . . . The brightest brick-red soils are to be found on the drier portions of the lowlands and the drier, low mountain slopes. With increasing precipitation, the soils become

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darker red, brownish-red, and brown. At varying depths below the surface, the pulverulent or clayey laterites pass rather abruptly into thoroughly decomposed but still compacted rocks which are brown, yellow, gray or green in color. The soils and sub-soils show none of the original textures or structures of the rocks from which they were derived; the weathered layers of lava below not infrequently have these more or less perfectly preserved. In the lower zones are great numbers of concentrically weathered boulders which often have at their centers spherical or ellipsoidal masses of relatively fresh rock from which the nature of the original lava can be determined. Still farther below the surface there is a gradual transition from the weathered to relatively unaltered rocks. The depth of the weathered zone apparently depends upon the amount of rainfall.

In the rainier sections of Kauai the dominant colors of the soils are brown, yellow, pink, and gray. These soils have lost a large part of their iron content and approach ferruginous bauxites in composition. The subsurface zones rapidly change in color to dark-brown or red. It is evident in the field that redeposition of iron oxide takes places abundantly below the bauxitic layers. Pulverulent masses of iron oxide fill practically every opening in the decomposed rock.

SOIL ANALYSES

The averages of soil analyses given in Table 10, compiled from data published by Kelley (41), doubtless present a very fair picture of the changes in composition which have taken place in the alterations of the basalts in the lowland areas of Kauai.

TABLE 10. AVERAGES OF SOIL ANALYSES

	1 AVERAGE OF 26 SOILS	2 AVERAGE OF 8 SUBSOILS	3 AVERAGE OF 26 SOILS AND 8 SUBSOILS	4 AVERAGE OF 10 RED SOILS	5 AVERAGE OF 13 BROWN SOILS
Insoluble residues	31.03	29.98	30.50	28.92	32.36
Al_2O_3	19.16	22.77	21.46	19.63	18.94
Fe_2O_3	21.50	20.57	21.03	15.27	18.75
MgO	1.32	.66	.99	.62	1.77
CaO	.60	.33	.46	.58	.56
Na_2O	.31	.36	.33	.34	.30
K_2O	.38	.31	.30	.32	.26
TiO_2	1.66	1.90	1.78	1.07	1.84
Mn_3O_4	.38	.42	.40	.30	.43
P_2O_5	.50	.40	.45	.57	.45
SO_3	.32	.32	.32	.36	.29
N	.12	.12	.18	.25	.24
H_2O	99.16	8.14	8.66	7.67	10.06
Volatile matter	10.05	14.57	12.31	14.97	15.06

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A comparison of the average analyses of the 26 soils and of the 8 subsoils (Table 10) with the best average analysis of the Kauai lavas now obtainable shows the increase or decrease in the proportion of the various constituents to have been as shown in Table 11.

TABLE 11. COMPARISON OF AVERAGE ANALYSES OF COLUMNS 1 AND 2, TABLE 10.

SOIL		SUBSOIL	
INCREASE	DECREASE	INCREASE	DECREASE
Al_2O_3	SiO_2	Al_2O_3	SiO_2
Fe_2O_3	MgO	Fe_2O_3	MgO
FeO	CaO	FeO	CaO
Mn_3O_4	Na_2O	TiO_2	Na_2O
P_2O_5	K_2O	Mn_3O_4	K_2O
SO_3	TiO_2	P_2O_5	
H_2O		SO_3	
		H_2O	

Table 12, compiled from data published by Kelley (41), gives the mechanical composition of 4 soils (Nos. 1-4) from Koloa, southern Kauai, and of 2 soils and associated subsoils (Nos. 5, 6) from Hanalei, northern Kauai.

TABLE 12. COMPOSITION OF KAUAI SOILS

	VOLATILE MATTER	FINE GRAVEL	COARSE SAND	FINE SAND	SILT	FINE SILT	CLAY
1	18.75	.02	1.57	5.48	6.49	33.40	33.50
2	19.90	.10	3.11	7.58	7.22	36.50	27.40
3	15.60	1.23		11.78	11.65	24.20	35.80
4	13.74	.34		5.72	4.65	33.20	39.10
5	21.41	.10	.40	9.58	12.78	29.01	27.24
	16.42	.12	.12	11.88	9.04	22.28	41.09
6	25.28	.24	.42	18.35	10.31	32.45	15.04
	19.21	.12	.45	26.89	13.37	20.69	20.92

In Table 13 is listed the average of 8 analyses of alluvial soils from Hanalei Valley, as given by Kelley (41). The alluvial deposits in the lower portions of the submerged river valleys of the eastern half of Kauai are the principal accumulations of transported soils. They are composed of basaltic débris with considerable amounts of organic material. At the mouths of the rivers, calcareous sand is present in considerable quantities, and may be the dominant constituent of the soil.

TABLE 13. AVERAGE OF ANALYSES OF ALLUVIAL SOILS FROM KAUAI

Insoluble residue	44.57	TiO_2	2.62
Al_2O_3	18.81	Mn_3O_4	.27
Fe_2O_3	16.38	P_2O_5	.49
MgO	3.46	SO_3	.29
CaO	1.13	N	.19
Na_2O	.30	H_2O	....
K_2O	.17	Volatile matter	12.56

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SEDIMENTARY DEPOSITS

The chief sedimentary deposits thinly veneer the coastal margins of Kauai, and have accumulated to depths of a hundred or more feet in the mouths of valleys crossing the emerged marine platform. Inland, there are local talus cones and aprons, stream gravels and boulders, and occasional small masses of iron oxides which have been precipitated in the pools of the highland swamps, but these inland deposits are of minor importance. The sediments for the most part are of Recent age; it is possible, however, that the basal sections of the discontinuous reef fringing the island and the lower horizons in the alluviated river mouths may date back to the closing stages of the Pleistocene, though no evidence on this point could be secured. The only sediments belonging to earlier stages of the island's history are: (1) boulder beaches which are found on the shoreward sections of the emerged marine platform; (2) beds of coarse conglomerate (the Waimea conglomerate) which are exposed near the base of Waimea and Olokele canyons at an elevation of about 500 feet. The ages of these older deposits could not be determined. Marine and terrestrial invertebrates, all Recent types, are found in the littoral deposits and in the sand dunes, and plant remains have been reported from borings made in the alluviated valley mouths. Unfortunately, none of the latter material was obtainable, so that specific identifications cannot be had. The results of microscopic studies of the various sediments have not been completed.

The sedimentary deposits of Kauai may be classified as follows:

1. Discontinuous, practically extinct, fringing reefs.
2. Clastic deposits of the littoral zone.
    a. Unconsolidated clays, sands, gravels, and boulders.
    b. Lithified beach sand and gravel (beach rock).
3. Emerged littoral deposits.
4. Sand dunes.
    a. Unconsolidated.
    b. Lithified.
5. Reef plain deposits.
6. Alluvial deposits.
7. Talus and landslide deposits.
8. Boulder beaches on the emerged marine platform.
9. Clastic deposits interbedded with the lavas of the main igneous complex.

The distribution of the principal areas covered by sediments is shown on the geological map of Kauai (Pl. XIII). As the various types of sediments merge into one another in many places accurate boundaries cannot be drawn.

THE FRINGING REEF

At various localities along the coast are patches of a narrow, practically extinct fringing reef (Pl. VII, *B*); these are naturally widest and most

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extensive on the windward (northern and northeastern) side, but even there are long stretches of reef-free coast. Off the steep northwestern cliffs only two small areas of reef are present, one near the mouth of Milolii Canyon and the other to the west of Nualolo Canyon; at a number of places, there are small colonies of reef-building organisms which can hardly be designated as reefs. An extinct fringing reef probably underlies the surficial deposits of the southwestern crescentic plain (Mana Flats).

The thickness of the Kauai reefs has not been determined. Some evidence may be gained from wells sunk at two places on the inner margin of the coastal lowland on the southwestern side of the island to obtain water for the Kekaha Plantation. Unfortunately, no log of the well was kept, and such samples as were taken have been lost. According to Mr. H. P. Faye, Manager of the Kekaha Plantation, the drills were driven "through the soil past boulders and into the solid rock" and continuous beds of lava were first encountered at depths of 250 to 325 feet below the surface (225 to 300 feet below sea level). The surface of the lavas is covered with a foot or two of soft material (probably weathered basalt), below which the drills went through 10 to 15 feet of very dense basalt. Below this dense rock, porous, fresh water-bearing lavas with occasional layers of dense material extended downward for 25 or 50 feet at which point the drilling was stopped. The water for irrigation is pumped from the porous horizons. No sedimentary deposits were encountered below the uppermost lava, which probably marks the surface of a submerged wave-cut platform upon which a reef grew or a limestone bank accumulated. This platform I correlate with the emerged marine plain on the eastern side of Kauai which was brought above sea level by the tilting of the island (p. 36). No information is available as to the nature of the boulders mentioned by Mr. Faye. Judging from the abundance of calcareous sand in the surficial deposits of the plain, an underlying reef limestone must have been its source. The boulders met in the drilling may be either limestone or masses of lava which have fallen from the cliffed highland behind the reef.

Between the mouth of the Wainiha River and Haena and at other places along the northern coast of Kauai, low plains have been developed by the deposition behind and over the reef of basaltic detritus from the highland and wind-blown, calcareous sand, derived from the disintegration of the practically extinct reef front and of shells lying along the shore (Pl. VI, *B*; IX, *A*). Along the shoreward margin, the surface soil is composed of calcareous sand, with small admixtures of olivine grains, basalt fragments, and weathered lava. Low dunes, rarely exceeding 30 feet in height, form a more or less continuous rampart along the shoreward edge of the plains behind the face of the reef (Pl. VII, *A*). Toward the base of the highland, the

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proportion of calcareous sand decreases, and basaltic detritus, including basalt and olivine sand, transported lateritic soil, coarse lava talus and stream lava boulders are the dominant components. The island is growing seaward at certain localities by this method of infilling behind the reef face. The surficial deposits of the southwestern (Mana) plain represent much more extensive accumulations which have completely buried the underlying limestone (p. 42).

The reefs about Kauai and the other windward Hawaiian islands are discontinuous and feebly developed. On Oahu, Setchell (54) found that the reefs are practically extinct. I observed the same condition on Kauai and Niihau. Apparently the reefs developed in late Pleistocene or Recent times in seas none too favorable for the reef builders; later they have been gradually killed off as certain elements in their environment became less satisfactory.

There is no evidence that pre-Glacial or inter-Glacial reefs existed about Kauai; the testimony of biologists is that the Hawaiian waters were not inhabited by corals until the close of the Pleistocene, but the principal components of the Hawaii reefs may not be corals. Certainly the present reef about Kauai is not growing on a subsiding basement. Kauai is not and apparently has not been a subsiding island.

The emerged, fringing reef on Niihau also has not grown up from a subsiding foundation. The northern, western, and southern portion of that island is a plain of low relief having a maximum elevation of about 125 feet at the base of the dome remnant which it borders. Most of this plain is surfaced by soil composed of basaltic and calcareous detritus. At a number of places, reef limestone is exposed at the surface; at others lava appears at or projects through the soil or limestone. Some of these lava masses are residuals of considerable size which were islands when the reef, underlying the surface soil, was growing about the island. Late extrusions of lava also have broken through the limestone in a number of places. At several localities, the contact between the limestone and the underlying lava basement is visible. The Niihau fringing reef apparently does not exceed 100 or 200 feet in thickness, and lies on a wave-cut platform which has a greatest width of about 8 miles. This island also remained relatively stable during the long period required for the erosion of the platform. Upon this the fringing reef flourished for a time and then the island was elevated.

The feeble character of the Kauai reef indicates its development in late Pleistocene or Recent times. If this assumption be correct, important sedimentary deposits would only be found along the outer margins of the platform, and the existing reefs would be merely thin pellicles rising from platforms which stand at no great distance below sea level.

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For Kauai, the evidence for the existence of pre-Glacial reefs is negative. No remnants of pre-Glacial reef limestone are preserved on the emergent wave-cut platform, which is present around half the circumference of the island. Of course, the width of the platform has been materially reduced by wave attack since its emergence, so that it is possible that some reef material existed along its outermost borders. It would seem, however, that remnants should be preserved where perhaps the reef reached its maximum width or in some specially favored spot. It is evident from the extent of erosion of the platform that the emergence took place prior to the close of the Glacial Period. The erosion of the valleys crossing the platform below the present sea level is assigned to the periods of the lowered Glacial oceans; certainly it has not been accomplished entirely in Recent time.

The development of the tapering spurs between the gorges running into the formerly sea covered area at the base of Waialeale indicates the presence of a protecting barrier in front of them, but such a barrier is offered by Nonou and Kalepa ridges which parallel the eastern shore. Furthermore, some of the spur ends appear to have been slightly snubbed, thus indicating that wave attack was active within the protected area. The northern face of Haupu Ridge is strongly cliffed, and this may have been accomplished in part by the sweeping of the ocean waters through the wide gap between Haupu and Kalepa ridges. On the northern side of Kauai the marine platform abuts abruptly against the cliffed spurs of the northern face of the Anahola Mountains, showing that there had been no barrier to wave attack in this section. On the southern side, the erosional topography is largely obscured by the development of post-Glacial tuff cones so that definite evidence regarding the operation of wave action is difficult to obtain. The rise from the marine platform to the basaltic highlands is abrupt, however, and there is little indication of the development of tapering spurs between the valleys.

On the western side of the island, the marine bench is absent, and the highland terminates in strongly dissected cliffs of great height which either plunge into the ocean or are fronted by low, coastal plains. It is evident that these cliffs were developed during a period of long continued wave attack, which is correlated in part with that required to erode the wave-cut platform exposed on the eastern half of the island. The western cliffs continued to be eroded long after the elevation of the marine platform, but are now protected by the constructional plain. On the northwest, the great, coastal fault line scarp is still being actively eroded by waves. The dissection and retreat of the crest of the cliffs and the recent nipping of their bases indicate that wave attack at the present level was interrupted for a time—probably during the period of lowered Pleistocene oceans.

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CLASTIC DEPOSITS OF THE LITTORAL ZONE

The clastic deposits of the littoral zone about Kauai may be divided into two principal groups: (a) Unconsolidated clays, sands, gravels, and boulders; (b) Beach rock (lithified beach sand and gravel).

UNCONSOLIDATED CLASTIC DEPOSITS

The unconsolidated clastic deposits of the littoral zone vary from place to place, depending upon the nature of the coastal topography, the presence or absence of the fringing reef, and the proximity to river mouths. Along the cliffed, reef-free shores, the deposits are composed chiefly of coarse basaltic boulders, with subordinate quantities of finer basaltic and calcareous detritus, which in part is derived in situ and in part has been drifted from other localities by waves and currents. The boulders are derived from the cliff faces as the result of undercutting of the base by wave action and the slump of unsupported rock above; and by landsliding of material loosened by weathering. Rock masses also are torn from the lower portion of the cliffs by the powerful storm waves. The boulders vary greatly in size; in form they are predominantly angular or subangular. Where the river valleys enter the ocean along the cliffed coast, fluvial deposits, which also may contain great boulders, are added to those of marine origin. The river-borne boulders are more or less rounded; the finer sediment is composed of basaltic sand and chemically weathered basaltic material. At many of the river mouths along the cliffed coasts, deposits of finer texture, consisting primarily of calcareous sand with smaller amount of basaltic débris, are frequently formed. The calcareous sand has been drifted along the cliffed coast from the limestone deposits of the windward portion of the island, and has lodged in the various indentations along the shore line. Few of these sand beaches last more than a few years, as storm waves sweep them away from time to time. New deposits may be formed within a short period, or may not be developed for several years.

The finer-textured deposits of the littoral zone are dominantly arenaceous; argillaceous sediments are relatively unimportant, except at the mouths of streams which are transporting only fine detritus. Even at such places, considerable quantities of calcareous sand are usually mixed with the clays. The littoral psammites are dominantly calcareous, but their composition varies within wide limits due to the presence of more or less basaltic débris. Four principal types may be recognized: 1, dominantly calcareous sands; 2, dominantly basaltic sands; 3, intermediate sands; 4, olivine sands.

The olivine sand beaches are less abundant than the others. Olivine is the dominant constituent, but basaltic and calcareous grains are also present in varying amounts.

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Most of the fine grained littoral sediments are temporary deposits lasting for comparatively brief periods. The severe storms of the rainy seasons not infrequently wipe out the accumulations of several years, or greatly alter the form and size of the deposit. Such changes are particularly noticeable at the reef-free river mouths and along the cliffed coasts.

Beach Rock

At a number of localities along the shores of Kauai the calcareous sands have been cemented into a more or less firmly indurated limestone to which the term "beach rock" is applied. The limits within which lithification takes place apparently are the high spring tide level and a depth not more than 10 feet below low tide level. Cementation of the loose calcareous sand takes place most readily along open coasts, where heavy surf beats more or less continuously against the shores. To a less extent, the process is in operation in partially protected localities, such as the shores of Nawiliwili Harbor, and behind the reef at Haena. Each of these localities, however, is subjected to powerful wave action, especially during the rainy season. The beach rock is composed primarily of calcareous sand, though small amounts of fine to medium-coarse basaltic débris are always present. In places, large basaltic boulders are included in the beach rock.

The sands about the shores of Kauai have been swept up from shallow depths off shore by storm waves. Powerful wave action apparently is necessary in the process of cementation, which takes place only a short distance above and below low tide level. The shallow depths of water at which beach rock was observed are constantly affected by movements of the surf, and very violently so during heavy storms. There is no evidence that the beach rock observed below low tide level was formed above sea level and later submerged; in fact, the most recent movements of the island have been in the opposite direction.

Pitted Shore Lavas

Where vesicular lavas are present along the shore line, the surfaces of wave-cut benches and of beach boulders are usually strongly pitted. The cavities are circular or elliptical in ground plan, and have nearly vertical walls. In size, they vary from small depressions little larger than the vesicles from which they apparently developed to tubes 6 to 7 inches in length and 2 to 3 inches in diameter. The pits are formed in part by solutions which have attacked the vesicle walls and in part by mechanical abrasion by sand and gravel lodged in the cavities and kept in motion by waves. Many lava flows along elevated shore lines and boulders of the emerged beaches show this pitting. Along the shore, marine animals, especially the echinoid (*Podofera pedifera*) and the limpet (*Helcioniscus exaratus*) make their homes in

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the cavities. Pitted boulders and surfaces are occasionally found in the lavas at various elevations throughout the island, but the cavities differ from those of the shore lavas in that they are more irregular in ground plan and generally are much shallower. Such depressions appear to have been developed by the enlargement of vesicles resulting from the action of ground water and atmospheric solutions. Mechanical abrasion apparently has not been important.

EMERGED LITTORAL DEPOSITS

At a few localities along the eastern shore of Kauai, littoral sediments have been exposed as the result of the Recent slight emergence of the island. The principal deposit forms a more or less continuous belt that extends from just north of Hanamaulu Harbor to a point about three-quarters of a mile south of Kealia; a second deposit lies between Kealia and Kapaa; and a third deposit of different character has been exposed by the building of the government road on the south side of Nawiliwili Harbor.

The deposits between Hanamaulu Bay and Kealia are composed of basalt and reef limestone boulders, finer basaltic detritus, calcareous sand, and abundant remains of marine invertebrates, embedded in a brick-red, sticky, lateritic clay. The deposit forms discontinuous lenses which vary in thickness and in the proportion of their constituents within relatively short distances. The exposed thickness of the series nowhere exceeds 6 feet. These sediments lie either on a somewhat weathered basaltic surface or upon nonfossiliferous, lateritic soils. At no place is the top of the series more than 15 feet above high tide level. The deposits are similar to those which are being formed at the present time at many places along the shore line.

The following list includes the fossils collected from the deposits between Kealia and Kapaa (column 1) and north of Hanamaulu Bay (column 2). The species have been identified by Professor Junius Henderson; all of them are Recent.

	1	2
Coral fragments, Fungia Porites	X	X
Undetermined echinoid spines	X	X
Anemia nobilis Reeve	X	
Chama sp.	X	
Spondylus sp.	X	
Cadakia ramulosa Gould		X
Venus reticulata Linneaus	X	X
Conus hebraeus Linneaus	X	
Conus lividus Hwass	X	
Conus striatus Linneaus	X	
Conus sp.	X	X
Cypraea caput-serpentis Linneaus	X	X
Cypraea isabella Linnaeus	X	X
Cypraea mauritiana Linnaeus	X	
Cypraea madagascariensis Smith		X
Cypraea reticulata Martyn	X	X
Cypraea sp.	X	X
Bittium, several undetermined sp.	X	
Eulima major Sowerby		X
Helcioniscus argentatus Sowerby	X	X
Helcioniscus exaratus Nuttall		X
Hipponyx antiquatus Linneaus	X	X
Melampus sp. undetermined	X	
Nerita picea Recluz		X
Patella sp.		X
Purpura aperta Blainville	X	
Ricinula ricinus Linneaus (Possibly Drupa sp.?)	X	
Scalaria sp.	X	
Strombus maculatus Nuttall	X	X
Triton cf. rubecula Linneaus	X	
Trochus sandwicensis Souleyet	X	X
Turbo chrysostomus Linnaeus	X	
Undetermined gastropods	X	X

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A third emerged beach deposit extends for perhaps a third of a mile east of the mouth of the Huleia River, along the Government breakwater road on the south side of Nawiliwili Harbor. This deposit is composed of dark, brownish or brownish-black, medium to fine grained sandy soil in which a considerable number of marine invertebrate shells are embedded. The top of the series apparently is about 25 feet above sea level. The shells collected from this locality unfortunately were lost. According to my notes, they include a number of species similar to those now living about the shores of Nawiliwili Harbor. The species appeared to differ somewhat from those listed above, and properly should, because the sands were accumulated in an estuary and not along the open ocean coast.

SAND DUNES

Unconsolidated Sand Dunes

Low sand dunes, few of them exceeding 30 feet in height, are present along most of the coastal margins of the southwestern lowland (Mana Flats) and the hinter-reef plains of other parts of Kauai, where there is a rapid accumulation of disintegrated limestone fragments by wind and wave action (Pl. VII, *A*). They are composed primarily of calcareous sand, but small admixtures of basaltic débris are present. Slight lithification was observed in certain of the deposits. Some fossiliferous horizons are present. In the dunes along the coast west of Haena there are some thin layers of blackish, basaltic soil mixed with more or less calcareous sand, which contain abundant shells of land snails. Otherwise, the fossils are of marine invertebrates.

The following species from the dunes west of Haena were identified by Professor Henderson:

MARINE INVERTEBRATES

Echinoid spines (Heterocentrotus sp.)
Chama sp.
Cadakia ramulosa Gould
Mytilus crebistriatus Conrad
Perna californica Conrad
Perna costellata Conrad
Venus reticulata Linneaus
Cerithium obeliscus Bruguière
Conus lividus Hwass
Conus hebraeus Linneaus
Conus sp.
Cypraea caput-serpentis Linneaus
Cypraea reticulata Martyn
Helcioniscus argentatus Sowerby
Helcioniscus exaratus Nuttall
Modulus tectum Gmelin
Nerita picea Recluz
Neritina granosa Sowerby
Patella sp.
Purpura aperta Blainville
Ricinula ricinus Linneaus
Sistrum morus Lamarck
Strombus maculatus Nuttall
Triton pilearis Linnaeus
Triton tuberosa Linnaeus
Trochus sandwicensis Souleyet
Turbo chrysostomus Linnaeus
Vermetus sp.
Small, undertermined gastropods.

LAND SNAILS

Carelia dolei Ancey
Lyropupa scabra Pilsbry and Cooke
Lyropupa rhabdata baldwiniana Cooke and Pilsbry
Nesopupa dispersa Cooke and Pilsbry

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Lithified Dunes

Along the southeastern shore of Kauai, east of Koloa, certain of the older calcareous sand dunes have been lithified, and later have been partially eroded by wave action, with the result that cliffs 20 to 25 feet in height have been cut into their seaward margins (Pls. IX, *B*, *C*). The dune sand is thinly laminated, and the cross-bedded structure is prominently developed. The stage of induration varies from place to place. The surficial layers have commonly been so thoroughly lithified that the granular texture has been practically obliterated. Solution at the surface has caused deep pitting; the intervening areas have commonly been reduced to sharp pinnacles of extraordinarily resistant limestone. Dana (19) who first described these lithified dunes, believed that the compact surface layers had been produced by the deposition of limestone in the depressions in which water commonly stands. Microscopic examination shows, however, that the granular structure is visible in the lithified crust; therefore, this crust has been formed by the deposition of calcium carbonate about the grains of the sandstone not only in the depressions, but also on the intervening areas. The induration of the material composing the pinnacles would hardly be as great as that of the floors of the depressions had the process operated as outlined by Dana. It appears that the cementation of the first inch or so of the surface layers has taken place by the solution of calcium carbonate at the surface, and its rapid deposition almost immediately below the surface.

SURFICIAL DEPOSITS OF SOUTHWESTERN LOWLAND AND HINTER-REEF PLAINS

In the deposits surfacing the southwestern lowland (Mana Flats) and the hinter-reef plains, a shoreward margin of calcareous sand is everywhere present. (See p. 42.) The sand is composed of fragments of the reef limestone and of shell fragments. The width of the calcareous margin varies, but is generally at least a third of the total width of the plain. Inland the percentage of basaltic detritus increases; on the wider plains, such as the southwestern lowlands, there is very little calcareous material at the base of the cliffs, but on the narrower plains, the amount of calcareous sand along the inner margins is relatively large. The basaltic débris consists largely of lateritized material, which has been transported from the highland by the streams which debouche upon the plains. Grains of unaltered basalt and of rather fresh olivine and magnetite are also common. The basaltic soil cover is generally brownish, dull red, or black in color. When mixed with considerable amount of calcareous material, the soils have a speckled appearance. At the base of the cliffs, an apron of talus and alluvial deposits usually is present.

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On the northern side of Kauai, the extinct fringing reef projects out for some distance beyond the detrital deposits; on the southwestern side, the materials have completely buried the underlying limestone.

ALLUVIAL DEPOSITS

The principal alluvial deposits occupy the lower portions of the stream valleys which cross the emerged marine platform (Pl. V, *A*). Deposits of less extent are present at various places in all of the stream channels and at the mouths of the valleys opening from the highland upon the plains.

The sediments of the submerged valley mouths consist primarily of reddish, brownish, and blackish lateritized soils with which are mixed minor quantities of more or less unaltered basaltic débris and a considerable amount of organic material. Upstream, these deposits merge into coarser sands and gravels, which floor portions of the valleys to slight depths. Wells bored in the bottom of Hanapepe Canyon about two miles from the shore passed through more than 100 feet of alluvial material, the lower 75 feet of which is below sea level. Borings for the supports of the bridge which crosses the mouth of the Wailua River were sunk through at least 80 feet of alluvium without reaching the underlying lavas. No exact records were kept of any of these borings, but according to Mr. J. Moro, who drilled the Hanapepe wells, certain of the beds passed through are as follows: "Dirt, soil, and river gravels—about 40 feet; logs were met in the gravels about 30 feet below the surface. At a depth of 50 feet is a hard, red soil, below which is porous soil. Lavas were first met at depths of 100 to 108 feet below the surface." In the mouth of the Wailua River, the deposits are described as sand, gravels, and clays. Masses of plant remains were encountered at some depth below the surface.

At the mouths of the streams, large quantities of calcareous sand are mixed with the laterized soil, so that the sediments become dominantly calcareous. A calcareous sand bar or spit is usually present at the mouths of the valleys, and across this the river maintains a relatively narrow connection with the ocean.

The formation of the alluvial flats has followed a submergence of the valley mouths. It has been suggested (pp. 38-39) that the streams eroded their channels below the present sea level when the oceans were lowered by the formation of the Pleistocene ice sheets; the submergence and consequent alluviation took place as the oceans returned to their normal levels. If this explanation be correct, the basal deposits in the valley mouths date back to the Pleistocene. As sedimentation continued the upstream portion gradually rose above sea level; the Recent slight emergence of the island has caused a further down stream extension of the subaerial phases, so that extensive areas are now flood plain and channel sediments veneering marine accumulations

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below. Branner (4) has described the alluviated mouths of certain great canyons on the eastern side of Kohala, Hawaii, and has attributed the submergence to a sinking of the mountain.

Above the alluviated portions of the marine plain valleys, the fluvial deposits are chiefly gravels and boulders. In the highland canyons, the deposits are much coarser in texture, and toward the heads of the canyons, are wholly made of very coarse gravels and boulders.

TALUS AND LANDSLIDE DEPOSITS

Because of the extreme ruggedness of the relief of Kauai, talus deposits are abundantly present. The great talus-alluvial aprons at the base of the highland cliffs along the hinter-reef plains of southwestern, western, and northern Kauai are the most notable examples. In places they exceed 200 feet in height. Talus cones and small landslide deposits are common in all of the deep canyons.

BOULDER BEACHES ON THE EMERGED MARINE PLATFORM

At a number of localities, particularly on the eastern section of the emerged marine platform, boulder beaches of considerable longitudinal extent are exposed. The deposits are composed of subangular or angular boulders of varying sizes; few of then exceed 3 feet in diameter. Boulders of vesicular lava commonly show pitting similar to that being developed in the vesicular lava along the present shore line. (See p. 70). No recognizable sediments of any type are associated with the boulder beaches. Apparently as the sea retreated during the emergence of the island, the finer, unconsolidated detritus was gradually swept seaward, and only the larger rock masses were left. The distribution of the beaches is rather difficult to ascertain, owing to the fields of sugar cane which obscure their relations, and to the fact that the boulders have been removed from many places in order to render the land available for cultivation. It seems, however, from a study of undisturbed deposits along the shoreward section of the eastern lowland, that there are a series of beaches, each marking a temporary still stand of the island during the period of emergence. The boulders in certain places are definitely related to minor wave cut terraces which were eroded into the platform during the course of the emergence.

The evidence favoring the accumulation of the boulder deposits by wave action is; (1) their distribution over the wave-cut platform; (2) the arrangement of the deposits where undisturbed, parallel to the present shore line; (3) the character of the pitting of the vesicular boulders. The age of the beaches is unknown, because the period of the emergence of the island cannot be definitely dated. The deposits antedate the basal alluvial sediments in the mouths of the valleys crossing the plains and the cutting of the

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valleys themselves. As it is considered that the valley alluvium in part is Pleistocene, the boulder beaches are older Pleistocene or even pre-Pleistocene in age.

CLASTIC DEPOSITS INTERBEDDED WITH LAVAS

In the bottom of Waimea Canyon near the mouth of the Poomau, and in Waialae and Koaie canyons, which also join Waimea Canyon, a coarse conglomerate is exposed. The deposits are composed of moderately well rounded boulders up to 3 feet in diameter mixed with gravel and sand. The whole is rather well indurated. The deposits are of sedimentary origin, and represent local accumulations upon an erosion surface during a rather long interruption in the volcanic cycle. Though the lower contact is exposed in only a few places, I think the evidence is sufficient to warrant the separation of the Kauai lavas into two groups at this break. (See pp. 56-57). I was not able to trace the conglomerate into other canyons, but this may be due to original local deposition, depth of rock weathering or to the heavy cover of vegetation.

DIASTROPHIC MOVEMENTS

CHANGES OF LEVEL

The tilted emerged platform, the submerged platform, and the submerged valley mouths provide abundant evidence that the Kauai dome has been subjected to notable changes of level at different times since the close of the last principal volcanic period (the late Kauai volcanicity).

The broad platform of the eastern half of Kauai (Pl. VI,*C*) is a wave-cut bench which was elevated by a tilting of the island along a northeast-southwest axis running from Hanalei Bay to the mouth of the Waimea River, (See pp. 35-36). That the emergence was not continuous is shown by the presence of a number of minor terraces which were cut into the platform during short periods of still stand. These subordinate benches are best developed on eastern Kauai where at least three can be recognized—one at 30 feet above sea level, a second at 50 feet, and a third at 100 feet. Other terraces and beaches may be present, but the sugar-cane fields which cover much of the platform obscure minor topographic features.

The principal elevation of Kauai does not seem to have been contemporaneous with that of Niihau. A wide, wave-cut platform borders the dome remnant of Niihau on the north, west, and south, but it does not stand so high above sea level as does the Kauai platform nor is there evidence of tilting during the course of its elevation. Much of the Niihau platform is covered by a thin fringing reef. As preglacial or interglacial reefs do not seem to have existed in the Hawaiian Archipelago, I consider that the elevation of Niihau took place late in the Pleistocene or in early Recent times after reef

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building organisms had found a foothold about the islands. Niihau therefore appears to have been elevated much later than Kauai. As these two mountains are parts of a single great volcanic structure, their different behavior requires explanation. The profound faulting which caused the disappearance of the eastern half of Niihau virtually broke the compound volcano in two, and subsequently the two sections behaved as more or less independent units. During the course of the faulting, the eastern or Kauai block was tilted toward the northeast and the emergence of the platform took place; the western side of the block was further submerged below sea level. The elevation of the Niihau block occured considerably later.

SUBMERGED WAVE-CUT PLATFORM

The evidence of the existence of a submerged platform along the western side of Kauai is meager enough. (See pp. 35-36). Records of wells drilled near Mana and Kaunalewa show that the drills passed through surficial soils and deposits of boulders for 275 to 300 feet below sea level, and then through a thin soil layer and into solid lava. Apparently the boulders overlie a wave-cut platform slightly weathered at the surface. This platform I consider to be continuous with that of the eastern two-thirds of the island. Probably it is not present at the above depths along the northwestern (Na Pali) coast, as faulting seems to have occurred there and a platform, if present, would have been carried to much greater depths below the sea level.

The mouths of the valleys crossing the platform and of the larger highland canyons have been cut at least 100 feet below the present sea level and subsequently have been submerged and partially alluviated.

RECENT CHANGES OF LEVEL

The proofs of recent changes of level on Kauai are: (1) wave-cut terraces—narrow rock benches at the base of the recent cliffs which have been cut into the emerged platform or into the base of the recently nipped headlands; (2) emerged sea caves; (3) emerged littoral deposits of various types.

Narrow wave-cut terraces 4 to 20 feet above mean sea level are present about the shores of Kauai, except off the constructional plain on the southwestern side. The main bench stands about 4 to 6 feet above sea level, though it varies somewhat in elevation from place to place (Pls. VI, *A*, *C*; VIII, *B*). Its average width is 20 to 30 feet, but in places exceeds 150 feet. The variations in elevations are caused by lithologic variations in the lavas, the presence of adjacent vesicular and nonvesicular areas, jointing, and variations in the dip of the flows along the sea coast. The most even-surfaced bench has been cut in the tuff cone and near-by sea stacks composed of the same rock north of Kilauea, northern Kauai. The terrace is definitely wave-cut; it transgresses the dip of the lavas and tuff beds into which it has been eroded. Other nar-

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row benches are present up to 20 feet above sea level, but they are not continuous for any distance about the island shores. Most of these are structural benches; they have about the same dip as do the flows. Some of the higher benches appear to truncate the flows, and may be of wave cut origin, but the evidence is not conclusive .

Further evidence of this recent change of level is providel by emerged sea caves which are fairly common along the steeply cliffed coasts of Kauai. Unfortunately, most of these caves are inaccessible because of the difficulty of landing. One to the south of Carter Point on the southeast side of the island was studied. This cave is 75 feet long, 79 feet wide at its mouth, and 35 feet wide at the back. The height of the mouth is 22 feet and of the back wall 8 feet. The lip of the cave now stands about 10 feet above mean sea level, the base of the back wall slightly over 20 feet. The lips of some of these emerged caves appear to be a little higher above sea level but accurate determinations could not be made. In the caves which are now being excavated, the lips appear to be 6 to 10 feet below mean sea level, hence the amount of emergence indicated by the dry caves is from 16 to 20 feet.

Recently elevated beach deposits are present at various places between Hanamaulu Bay and Kealia. The tops of these beaches are not more than 15 or 18 feet above sea level. The emergence of these deposits certainly is to be correlated with the recent change of level, because the fossils found in them are of types living about the shores of the island today. The sediments were formed just above and below sea level, consequently they now stand at higher elevations than the terraces which were cut at depths of 8 to 12 feet. The change of level indicated by these deposits is about 15 feet.

Wentworth and Palmer (63) have described terraces standing 4 to 12 feet above sea level on all of the Hawaiian islands and on other islands in the North Pacific. In conjunction with similar evidence obtained in other parts of the world, these writers believe that a negative shift of ocean level of 12 or 15 feet has taken place. In his recent paper on the geology of St. Helena Island, Daly (17, pp. 80, 81) gives the figure as 15 or 16 feet.

FAULTING

It is apparent that extensive faulting has taken place on Kauai, but exact location of the faults and the amount of displacement along them is practically impossible to determine because of the difficulty of tracing the dislocations in homogeneous rocks, the great amount of weathering and of erosion which have occured, and the heavy cover of vegetation in many critical places. The principal movements along the faults were completed early in the erosional period; no evidence of recent movements was observed. The most certain faults are indicated in figure 12; others undoubtedly are present, but the evidence for their existence is insufficient to justify mapping. The evidence

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for faulting is almost entirely physiographic; actual traces of fault planes were found in only a few places, and these unfortunately are on insignificant fractures.

The clearest example of extensive engulfment is the great volcanic sink between Anahola Mountains and Haupu Ridge, the development of which does not seem possible on any other hypothesis. (See p. 29). The depression may represent the enlargement of a summit sink of the Kilauea type which existed during the volcanic period, or it may have originated after

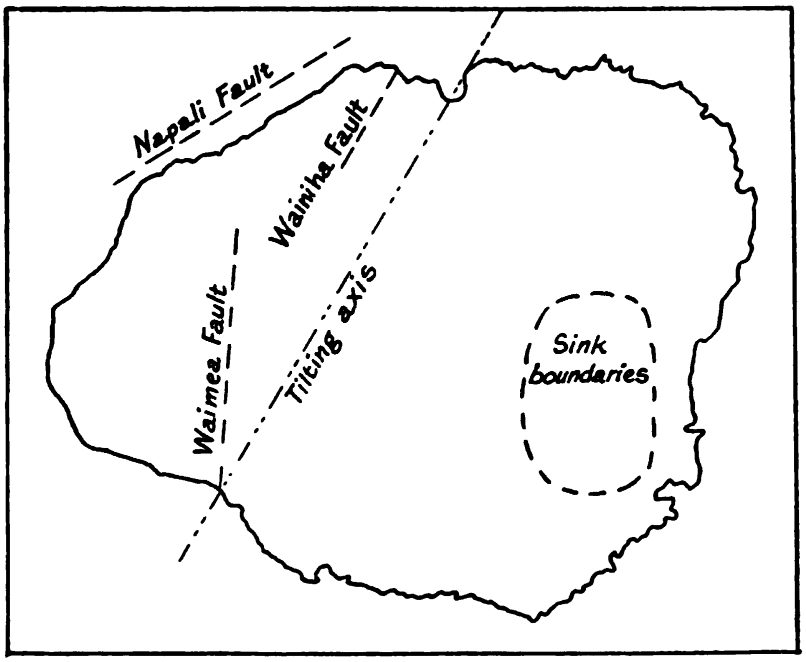

FIGURE 13.—Fault map of the island of Kauai. The positions of the faults were determined principally from physiographic evidence and consequently are only approximate. The axis along which the tilting of the island took place is also shown. Scale: 1 inch=9.7 miles.

all eruptivity had ceased; no evidence favoring either view was obtained. It is impossible to locate the faults bounding the depression, but I have the impression that the relations were similar to those of Kilauea, though on a larger scale. The present dimensions of the floor are 9 miles in a north-south direction and 6½ miles in an east-west direction. The size and depth of the sink may have been increased by fluvial and marine erosion which went on after the engulfment. The faults indicated on the map (fig. 13) as marking the present margin of the floor may not be accurately located. They are drawn merely to indicate that the depression is of tectonic origin.

Dana (19) and also Powers (52) have described the great line of cliffs on the northwestern side of Kauai (the Na Pali coast) as a battered fault scarp, and certain evidence, such as the straightness of the cliff line and im-

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portant breaks in the submarine contours favor this explanation. The present cliffs constitute a fault line scarp rather than a fault scarp; wave action certainly has caused some retreat from the line or zone of dislocation, but the amount of this retreat can not be determined from a few soundings which have been taken off this coast. To the east and to the west of the fault line scarp, the cliffs are of marine origin.

The aberrant course of the Waimea River seems to have been determined by a fault zone traversing the island in a north-south direction. (See p. 36). The block on the west stood higher than that on the east, and consequently deflected the drainage from the summit plateau, and made it tributary to a north-south trunk stream.

Faulting also seems to have controlled the location of parts of the courses of other streams on Kauai (for example, the lower portion of the Wainiha), but the evidence is so uncertain that no proof can be advanced in support of this statement. Other fracture lines are indicated by the linear distribution of some of the cinder cones, but they have produced no other topographic expression.

The amounts of displacement along these fault zones cannot be ascertained.

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RELATIVE AGES OF HAWAIIAN LANDSCAPES

IS KAUAI THE "OLDEST" HAWAIIAN DOME?

In literature dealing with the natural history of Hawaii, Kauai is commonly described as the "oldest" island of the windward section; that is, the close of the last principal eruptive period there first took place. Because this island has suffered the most extensive modifications of its initial outlines, the argument is advanced that the posteruptive history must have been of longer duration than on any other dome in the windward group. Also, evidence derived from the highly specialized nature of the flora and fauna and from the depth of rock weathering has been cited in favor of this view. Dana (19; 21, p. 311), states that "the valleys of Kauai are as much more extensive than those of the other islands of the group as its peaks are more irregular, abrupt, and broken" and that "the valleys and peaks [of Kauai] indicate that its fires long ago ceased,—as long ago as those of eastern Oahu, if not before." In order of extinction of the principal Hawaiian vents, Dana places Kauai first.

Dutton (23, pp. 83, 84) says of the older domes in Hawaii

> . . . we have no means of judging the antiquity of their final action except by the progress made by erosion in demolishing them, and this progress is, in every instance, considerable. It is most conspicuous on Kauai and Oahu, and almost equally so on Molokai and west Maui. From this it is inferred that the western islands of the group have longest enjoyed immunity from eruption. Kauai, especially, is frequently spoken of as the oldest of the group, and judging from the amount of destruction wrought upon it by the eroding forces, the statement is in some measure justified—but only to this extent: the period which has elapsed since the cessation of eruption has probably been longer than in any of the other islands. It does not follow, however, that the eruptions began here any earlier than on Hawaii. Whether they did or not is a question which I see no way of determining.

Among later writers Hitchcock (40, p. 14), Cross (7, p. 9), Powers (52, p. 501), Bryan (5), Martin and Pierce (45, p. 37) and Wentworth (62, pp. 131, 132) have considered that the extreme dissection of Kauai establishes its greater age.

None of these investigators seems to have studied the morphologic development of the Hawaiian domes in general or that of Kauai in detail; else different conclusions must have been reached. Also, none has considered the varying rates of marine and fluvial erosion in different parts of the islands, a vital factor in estimating the ages of the present landscapes. Furthermore, the importance of faulting in causing modifications of the initial outlines has largely been lost sight of.

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EVIDENCE APPARENTLY FAVORING GREATER AGE OF KAUAI

Certain lines of evidence seem to favor an earlier close of the last principal eruptive period on Kauai:

1. The topographic map shows that Kauai has suffered somewhat greater erosional modifications than has Oahu, West Maui, Lanai, Molokai, and the Kohala section of Hawaii.

2. The principal streams of Kauai are more numerous and are more permanent and less variable in their flow than on any of the other mountains; a longer time is inferred for their development. With the exception of a few streams on windward (eastern) Mauna Kea, Hawaii, those of Kauai have the largest average volumes.

3. Kauai has suffered extensive inroads from wave attack, but the evidence as yet is insufficient to prove whether greater destruction has been wrought than on Oahu or Niihau. The origin of the cliffed shores of these islands and the lengths of the time which have been required for their development need further investigation. The cliffed coasts of northeastern Molokai, eastern Niihau, and the northwestern coast of Kauai are considered fault scarps or fault line scarps. The cliffs of western Kauai, western Niihau, northern West Maui, southeastern Molokai, western Molokai, and eastern Mauna Kea, Hawaii, certainly have been cut by waves.

4. Botanical and zoological evidence seems to favor the greater antiquity of the present Kauai landscape. Hillebrand (30, pp. XVIII-XXII), the pioneer in botanical work in Hawaii, writes:

> As the age of the various islands increases in progression from east to west, it may be inferred that the richness in endemic species will stand in the same ratio. Kauai is not only richest in species but has them on the whole more differentiated.

Bryan (5, pp. 103, 193), apparently quoting from Hillebrand, states:

> . . . the number of endemic plants . . . is largest on Kauai and the smallest on the large island of Hawaii. . . . Disintegration of the lava has proceeded farther here (on Kauai) than on the other islands, a fact taken in connection with other data as indicating that the volcanic fires died out first at this end of the chain.

From observations on other Hawaiian islands, I consider the validity of the statement regarding the deeper weathering of the Kauai lavas doubtful; at least before it can be established much more evidence must be obtained from all parts of the group. In Hawaii, the depth to which rock alteration has proceeded is not necessarily a measure of the age of the lavas, but rather of the amount of rainfall in a given area and the ease with which the groundwater solutions can penetrate the rocks. On the various domes, the zone of weathering is deepest on the rainy windward flanks and in these sections varies with the rainfall.

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According to Hitchcock (40),

the confirmation of our belief in the greater antiquity of Kauai over the other islands is derived from the study of plants. . . . Taking the extremes, it may be stated that the flora of Mauna Loa is the poorest and most uniform and that of Kauai is the richest and most individualized in species.

From studies of the distribution of the Achatinellidae in Hawaii, Pilsbry (49) has concluded that all the Hawaiian islands once were united into a single land mass: "Volcanic activity built up the older masses, subsidence followed, Kauai being the first island dismembered from the pan-Hawaiian area."

Campbell (6, p. 268) writes: "The flora of Kauai is not only richest in number of species, but the species are most highly specialized and many are found exclusively on this island, indicating an early separation of the island from the other members of the archipelago."

There seems to be no geological evidence favoring such a former continent or series of continental islands. Biological necessity alone has called it into being.

In regard to the biological evidence, the question may be raised whether the greater abundance and differentiation of the Kauai species has taken place because of the longer time available or because of an environment more favorable then on the other mountains. The least diversity of the flora and fauna naturally appears where volcanic activity has longest prevailed. This subject has not yet received sufficient investigation to accept the biologic evidence as final in the problem of the age of the islands.

5. The fact that the migration of volcanic activity in the Hawaiian range has been in general from west to east is significant, but it does not establish the exact order of cessation of the last principal volcanic epoch at the various centers. The Kohala dome of Hawaii, for example, is associated with two active and two recently extinct domes; yet Kohala is older than eastern Maui and possibly also other domes lying to the west. The sealing of the principal eruptive areas therefore has not taken place in orderly fashion from west to east.

On the doublet islands, Oahu, Molokai, and Maui, the western member of each became extinct before the eastern, and has been partially buried by the lavas of the younger volcano. If this relationship holds for the Kauai-Niihau doublet, Niihau which lies to the southwest of Kauai, is the older of the pair.

The evidence which has been cited seems to favor the greater age of the present Kauai surface, but, in all of the morphologic discussions, the highly important factor of the rates of weathering and erosion on the various domes and on different sections of the same dome has received practically no con-

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sideration. Furthermore, insufficient attention has been paid to the loss of mass of the cones resulting from engulfment.

RELATIVE AGE OF KAUAI

In determining the length of time required for the erosional modification of originally similar land forms which are composed of rocks of about the same resistance to weathering and erosion and varying only slightly in their structural details, the degree of dissection of areas which may be selected for comparison will represent a fairly exact measure of the time intervals provided the rates of degradation prevailing over the various areas are approximately equal. On the other hand, because physiographic stage is not necessarily a measure of age, the dissection of regions in the same stage of the erosion cycle may have required vastly different lengths of time, hence the factors controlling the rate of erosion must be examined in detail. In areas such as the Hawaiian Archipelago, where the rocks are more or less uniform in their resistance to weathering and erosion, and where the structures of the mountains show few variations, the speed of weathering and erosion becomes the determining factor in the amount of removal which takes place within a given period of time. There are notable differences in rainfall over the various domes and over different sections of the same dome which affect the number, size, and fluctuations in volume of the streams. (See p. 46). There the rates of erosion over different sections of the same mountain and over similarly located sections on the various mountains are far from uniform. Domes which became extinct at approximately the same time have not been eroded to the same extent, and certain domes which have been long extinct have been less deeply dissected than those on which the last major volcanic period prevailed considerably longer.

The windward sections of all of the volcanoes have been more deeply eroded than the leeward; the constructional surfaces of the older domes have been almost completely destroyed on the windward side and are much broken on the leeward. On the younger mountains, conic sections of the constructional surfaces separate the windward canyons, while the leeward slopes have been little dissected. The summits of the highest peaks, Haleakala, Mauna Loa, and Mauna Kea, project above the zone of maximum rainfall, hence they are almost unbroken by erosion. On the low islands, Niihau, Lanai, Kahoolawe, and western Molokai, because of the light rainfall there are no permanent streams, and the rate of fluvial erosion has been extremely slow; changes wrought by wave action are much more important.

It is evident that engulfment also has greatly altered the form of certain of the domes; this subject has received insufficient consideration in papers dealing with the morphology of the islands. The loss of bulk on the part of a lava dome is not necessarily a measure of the amount of erosion which

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has taken place, as, on Kauai, Niihau, eastern and western Oahu, eastern Molokai, and probably also the Kohala section of Hawaii, down faulting has been one of the principal causes of the change in the initial outlines.

From the information available, it appears that the rate of removal on Kauai is somewhat more rapid than on any other section of Hawaii, and that, in consequence, the existing relief of the dome is most highly differentiated. Furthermore, extensive engulfment has played a significant part in the generation of the present topography. I believe that it is impossible to regard the landscape of Kauai as the oldest in the windward section of the archipelago; that it belongs to the oldest group is unquestioned, but the last principal volcanic period may have closed as soon on eastern and western Oahu, and West Maui. Niihau I regard as an older mountain than Kauai.

Evidence as yet is insufficient to determine the sequence of extinction of the principal vents in the Hawaiian islands. The problem of the low, semidesert islands needs special consideration. The small amount of fluvial dissection of these mountains is not a factor of age but of deficiency in rainfall over their surfaces. They may be quite as old as or even older than the deeply dissected domes with which they are associated. Certain general relationships of course are evident; Mauna Loa and Kilauea, the still active volcanoes are the youngest of the group; Hualalai, Mauna Kea, and Haleakala constitute the next series. Of these the principal eruptive period last became extinct in Hualalai; the relative antiquity of Mauna Kea and Haleakala may be debated, though the general concensus of opinion makes Haleakala the older. It is certain, however, that minor activity has prevailed longer on Haleakala than on Mauna Kea. The landscapes of both West Maui and eastern Molokai apparently are somewhat younger than those of eastern or western Oahu or of Kauai, although this is yet to be positively established. As to the relations between Kauai and eastern and western Oahu, little can be said. The place of the four low islands, western Molokai, Lanai, Kahoolawe, and Niihau also has yet to be determined. Wentworth (60) believes that "Lanai is younger than any part of Molokai and is older than east Maui or Kahoolawe. Lanai and western Maui may be of nearly simultaneous origin with the probability that if a difference of age exists western Maui is the older."

SUMMARY

Our present knowledge shows that the windward Hawaiian mountains may be divided into four groups: 1. The still active domes—Mauna Loa and Kilauea; 2. the recently extinct domes—Hualalai, Mauna Kea, and Haleakala; 3. the old, deeply eroded domes of medium elevation—Kohala, West Maui, eastern Molokai, eastern and western Oahu, Kauai; 4. the old, low, arid islands—western Molokai, Lanai, Kahoolawe, and Niihau.

The constructional surfaces of the older domes have been largely destroy-

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ed either through the action of erosive agents alone or by erosion and downfaulting; on the younger domes, great sections of the constructional surface remain. Faulting has profoundly modified the initial outlines of eastern Molokai, eastern and western Oahu, Kauai, Niihau, and Kohala. Important changes in outline and topography have resulted from changes of level.

Mauna Loa and Kilauea (Group 1) are still active; their relative ages have been disputed, but the opinion now held by Jaggar, Finch, and others is that Mauna Loa is the older. The order of extinction of the principal vents on the recently extinct domes (Group 2), has been: (1) Haleakala; (2) Mauna Kea; (3) Hualalai. Subordinate activity has taken place at minor centers on Hualalai in the last century, on Haleakala in the eighteenth century, but on Mauna Kea there is no record of a historic eruption.

Regarding the time of close of the last principal volcanism on the older domes, there is little positive information. West Oahu, western Molokai, and West Maui each became extinct prior to the eastern members of these doublets; volcanic activity probably ceased on Niihau before it did on Kauai; Kohala evidently is the oldest dome on Hawaii.

The degree of topographic modification of the older group of domes ranks as follows: 1, Kauai and East Oahu; 2, West Oahu; 3, eastern Molokai; 4, West Maui; 5, Kohala.

The place of the low, arid mountains in the sequence is much more difficult to determine, as little is known of the rates of erosion on them as compared with the higher, older domes. Niihau I believe to be older than Kauai; west Molokai became extinct before east Molokai; Lanai and Kahoolawe both are older than East Maui; Lanai and Kahoolawe probably are of about the same age as West Maui. Beyond these unsatisfactory statements it is unsafe to venture at present.

The principal volcanism apparently ceased on Haleakala, Mauna Kea, and Hualalai in the Pleistocene, though Hualalai may have seen activity at its principal center in Recent times. The older, higher domes doubtless became extinct in the Pliocene and early Pleistocene. The dating of these events must be made from studies of the rates of erosion on the various domes together with the topographic modifications which have taken place. The loss of mass by engulfment also needs full consideration.

RATES OF EROSION IN HAWAII

Erosion by Streams

In Table 14 is given the number of permanent and intermittent streams on the windward and leeward sides of the various Hawaiian domes. The extent to which tributary streams have been developed is also indicated.

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MARINE EROSION

The amount of wave erosion about the shores of the Hawaiian domes is an important factor in determining the relative age of the various landscapes. In general, similarly exposed coasts have been abraded at about the same rate, though there is the possibility that, during the Glacial epochs, the speed of removal may have been different than under present climatic conditions. This would affect comparisons of the rates of marine abrasion about islands which

TABLE 14. PERMANENCY OF STREAMS ON THE HAWAIIAN DOMES.

	WINDWARD		LEEWARD		
	Permanent	Intermittent	Permanent	Intermittent	Tributaries
Niihau	....	3	....	21	Few
Kauai	59	2	14	60	Many on large windward and leeward streams; few on most leeward streams.
West Oahu	....	22	....	12	Few
East Oahu	25	7	31	28	Few
West Maui	7	60	3	50	Many on windward and large leeward streams; few on small windward and most leeward streams; some leeward streams permanent in upper courses.
East Maui[a]	....	....	....	....	
West Molokai	....	11	....	27	Few
East Molokai	12	19	2	64	Many in upper courses of windward streams; few on small windward and all leeward streams.
Lanai	....	27	....	16	Few
Kahoolawe[b]	....	....	....	....	
Hawaii					
Kohala	49	6	....	23	Many in upper courses of large windward streams; few in small windward and in all leeward streams.
Mauna Kea	116	20	[b]	....	
Mauna Loa[c]	....	....	....	....	
Hualalai[c]	....	....	....	....	
Kilauea[c]	....	....	....	....	

[a] Permanence of flow of 71 streams not indicated; [b] no record; [c] record incomplete.

had become extinct during the late Tertiary or early Pleistocene and those which became extinct in the late Pleistocene or Recent periods. The rate of removal about the windward shores of Lanai and Kahoolawe probably is slower than that along the windward shores of the other domes, because of the protection afforded these islands by the great bulk of Maui to the east. The strong cliffing of the leeward coasts of Kauai, Niihau, Lanai, and Kahoolowe introduces a special problem. This cliffing may have taken place when the climatic belts were differently arranged than at present. During the Glacial epochs, it is quite possible that the belt of the stormy westerlies may have been shifted as far south at the latitude of Hawaii. Under such conditions, the chief wave action would have been along the leeward rather than along the windward coast as at present. Faulting has played an important

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part in the development of coastal topography in Hawaii. The eastern coast of Niihau, the northwestern cliffs of Kauai, the magnificent northern face of east Molokai, the northeastern cliffs of Kohala, and part of the southwestern coast of Mauna Loa and Kilauea are fault scarps or fault line scarps. Various sections of the Lanai and Mauna Loa coasts are true fault scarps; the other cliffs probably have been driven back for some distance from the zone of dislocation by the powerful wave attack at their base.

EFFECTS OF EROSION

The climatic and hydrographic data indicate a more rapid rate of erosion over most of Kauai than over any other of the older mountains in the archipelago; therefore the great amount of fluvial removal has not necessarily taken a longer time, but has proceeded at a more rapid rate. Also, a great section of eastern Kauai has been partially destroyed by engulfment. Comparing the series of events recorded in the development of the present landscapes of Kauai and of eastern and western Oahu, it appears that the last principal volcanism ceased first on the Oahu domes. The rate of erosion over eastern Oahu is slower than over Kauai because of the somewhat lighter rainfall and because of the much smaller area of its principal watershed. Western Oahu had been deeply eroded by streams and waves before the growth of the eastern volcano, but, as this mountain was built, it formed a great barrier in the path of the Trade Winds, and gradually lessened the precipitation over western Oahu. The streams became intermittent, and the rate of fluvial removal became relatively slow. Erosion of the eastern mountain has been rapid, and its surface is now more highly dissected than that of its older neighbor. Niihau I believe to be older than Kauai, though the difference in the ages of their landscapes probably is not very great. Morphologic comparisons are difficult because of the vastly different rates of fluvial removal over the two islands. So far as marine removal is concerned, the emerged, wave-cut platforms about the two islands are of about the same width, but that on Kauai is on the windward side, whereas the Niihau platform is on the leeward side. As the average rate of wave erosion probably has been greater on the present windward side of both islands, it would appear that the platform of Niihau has taken a longer time to be developed. However, the Niihau platform did not emerge until after that of Kauai. Whether these opposing factors can be balanced I think is doubtful.

Regarding eastern Molokai, West Maui, and Kohala, I believe that present knowledge of their climates, drainage systems, and morphologic changes indicate that the landscape of West Maui is the oldest, that of eastern Molokai the next, and that of Kohala the youngest. All of these domes became extinct after Kauai, Niihau, and the two volcanoes of Oahu.

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The problem of the order of extinction of the various domes merits much further study. The chief points to be borne in mind are the relation between physiographic stage and rate of erosion and the extent of down faulting. In Hawaii the rate of erosion is largely a factor of climate.

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NIIHAU

EXTENT OF INVESTIGATIONS

Little geological work had been done on Niihau prior to my visit in 1921. Hitchcock (40) and also Bryan (5) make brief mention of the island and Powers (53), who spent a few hours on Niihau, collected a number of samples of the lavas, some of which have been analyzed by Washington and Keyes (59).

Through the kindness of the owner, Mr. Aubrey Robinson, I was able to spend eight days on Niihau and to visit most parts of it. The time was sufficient for examining the salient features of the geology and morphology and for collecting systematic suites of the igneous rocks, sedimentary rocks, weathered rocks, and soils. At the time of my visit the topographic map of the United States Geological Survey (published in 1929) was not available, hence it was necessary to base the geologic studies on such sketch maps as could be obtained.

GEOGRAPHY

Semidesert Niihau is a roughly elliptical island, lying about 17 miles southwest of Kauai from which its steeply cliffed eastern coast is usually visible. It has an area of 97 square miles, a north-south length of 18 miles, and a maximum width of 5 miles. A small, dissected and strongly cliffed lava dome remnant forms a portion of the eastern side of the island; bordering this on the north, west, and south is a low plain which stands from 50 to 100 feet above sea level. The highest point on the dome remnant is 1,281 feet above sea level.

The only rainfall records are kept at Nonopapa, where an annual maximum of 35 inches has been measured. The average annual precipitation at this station and over the whole island is considerably less. The rains are widely separated in point of time, and months or even more than a year may pass with little or no rain on any part of the island. The low elevation is responsible for the aridity of the climate; only occasionally do cloud caps form about the highland, a condition strikingly contrasted with that on neighboring Kauai. There are no permanent streams; the valleys are filled now and then with torrential floods which may flow for a few days, but for months at a time no water flows through them. The contrast in the climate of Kauai and Niihau naturally is reflected in epigene profiles of the two islands; ocean waves have been a much more effective erosive agent on Niihau than have streams.

Because of its dry climate, Niihau is unforested, and the plant cover in most places is more or less broken. A few scattered native trees and shrubs,

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such as the milo, the wiliwili, the hau, and the *mao* grow in the highland valleys and on the lowlands at or near the valley mouths. Of the exogenous plants, the algaroba (*Prosopis juliflora*) is most important, because it grows rapidly under arid or semiarid conditions; the wood makes excellent fuel, and the numerous seed pods afford food for cattle and sheep. The principal vegetation is a grass cover, continuous or broken, depending upon the soil in which it grows. On the sand hills along the coast, the *kolakola* and *Convolvulus* are the principal species.

Most of the fresh water on the island is collected from the scanty rainfall. Borings into the rocks of the lowlands have yielded small quantities of fresh water, but the flow soon becomes more or less saline because of the penetration of ocean water through the cavernous and porous rocks, once the head of fresh water had been drawn off. A few brackish springs in the highland provide additional water. On account of insufficient water supply, agriculture is impossible in spite of the evident richness of the soil.

The island is used as a stock ranch. When the scanty rains are not interrupted by too long periods of drought, there is sufficient pasturage for 20,000 to 30,000 head of sheep and more than 1,000 cattle and horses. During the not infrequent long dry spells, the problem of supplying the animals with sufficient water is a serious one, and it is usually found necessary to reduce the number of sheep.

The population of Niihau, according to the census of 1920, was 191; the inhabitants, with the exception of the ranch foreman, are Hawaiians, though of course, many are not full blooded. Originally the island had a large Hawaiian population.

A few roads go over the lowland from the principal settlement at Nonopapa to various parts of the island. There are many trails, and all parts of the island are accessible, as there is no dense cover of vegetation at any place.

There are no natural harbors. The chief landing is offshore at Nonopapa; a second one is off Kii on the east coast. Inter-island boats stop at Niihau at irregular intervals, generally to load or unload cattle or sheep. Communication with Kauai is usually carried on by means of Japanese fishing sampans. Niihau is not connected with Kauai or Honolulu by either wireless or cable.

MORPHOLOGY

General Relations

Niihau, like Kauai, is a single lava dome which was originally larger and higher. Down faulting has caused the subsidence below sea level of the eastern portion of the dome and a considerable part of the residual mass has been destroyed by wave action. Judging from the present shape and size

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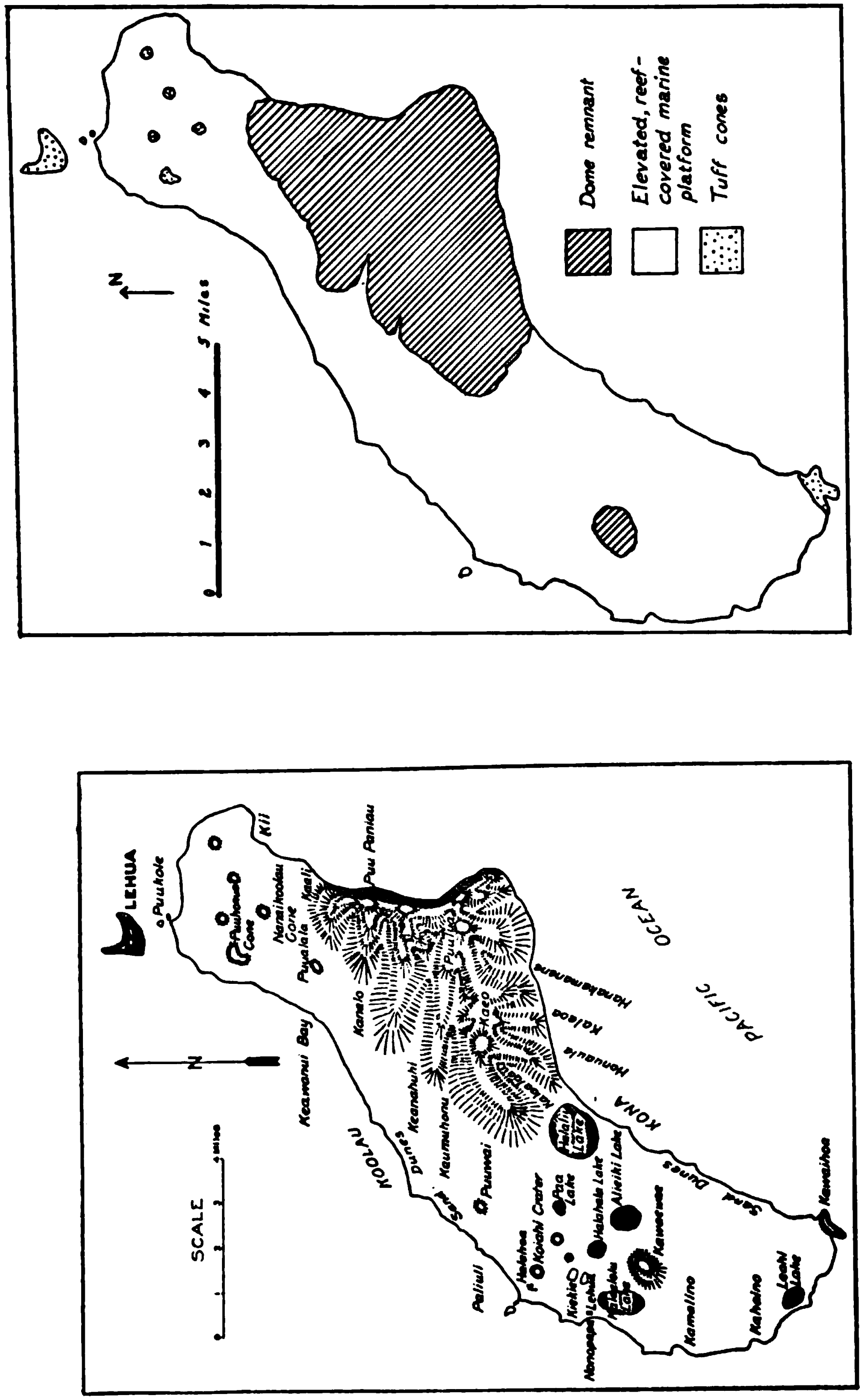

FIGURE 14.—*a*, sketch map of Niihau based on a map published by Powers (Am. Jour. Sci., vol. 50, p. 258, 1920); *b*, physiographic map of Niihau.

of the island, it originally must have been about 18 miles long, 10 miles wide, and more than 3,000 feet high. Its dimensions probably were similar to those of Lanai. Niihau now consists of two sharply differentiated physical divisions (fig. 14): (1) a small, rudely triangular, strongly cliffed and dissected dome remnant composed entirely of westward dipping flows; the northwestern side of the remnant is 9 miles long, the eastern side 4 miles, the southern side 8 miles. Its maximum elevation is 1,281 feet above sea level. (2) Bordering the volcanic mass on the north, west, and south is a low plain whose elevation does not exceed 50 or 100 feet at the base of the highland cliffs (fig. 14, *b*). This plain was formed by the emergence of a wide, wave cut platform partially covered with a thin fringing reef.

Dome Remnant

Because, at a former time, the Niihau dome-remnant was exposed to wave attack on all sides, its margins are strongly cliffed. Marine erosion has been more effective than fluvial erosion, hence wave-cut features are the most conspicuous elements in the relief. The eastern coast, which is a fault line scarp, stands in the path of the northeast trades, and hence is exposed to most active abrasion. The great wall rises to an elevation of about 800 feet at the southern end and to more than 1,000 feet at the northern end. Very few valleys break its face, and the sheerness of the declivity is maintained by the active abrasion at its base (Pl. XI, *A*). The southern cliffs decrease in elevation to about 300 feet at their western extremity. Because this side of the residual is more sheltered, the coast is less steep and more valleys have been eroded into it. On the northwestern side, the cliffs increase in height from about 300 feet at the southern end to more than 1,000 at the northern end. These cliffs have been much more extensively dissected because of the protection long afforded them by the emerged reef-covered platform at their base and because the principal slope of the residual and hence of the drainage is directed toward them.

The scarp forming of the eastern cliffs was produced when more than half of the island was down faulted below sea level (p. 53). Since then, the cliffs have retreated under the powerful wave attack at their base. A submerged platform, about 2 miles wide, indicated by soundings off southeastern Niihau, perhaps measures the amount of wave erosion which has taken place since the engulfment. Within 4 miles of the cliffed coast, depths of 319 to 516 fathoms have been measured. A sharp change in slope thus is suggested at the edge of the platform, and this change I believe represents the position of the rift zone.

Although stream action at the present time is relatively ineffective, the constructional surface has been considerably eroded (Pl. XII, *B*). The time involved in the dissection of the dome remnant is indicated both by the slow

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rate of fluvial removal and the extent to which waves have attacked the island. As the original elevation of the dome was probably more than 3,000 feet, the precipitation over its surface before the engulfment took place must have been somewhat greater than at present. It may have equalled or exceeded that over Lanai, where a maximum yearly average of 50 inches has been measured. The pre-engulfment streams very likely were much more effective eroding agents than are those of the present, hence it is possible that canyons of considerable size had been eroded into the windward side of the mountain. Whether erosion of the leeward flanks had commenced before the down faulting of eastern Niihau cannot be determined. The existing section is a part of the former leeward portion of the dome. The

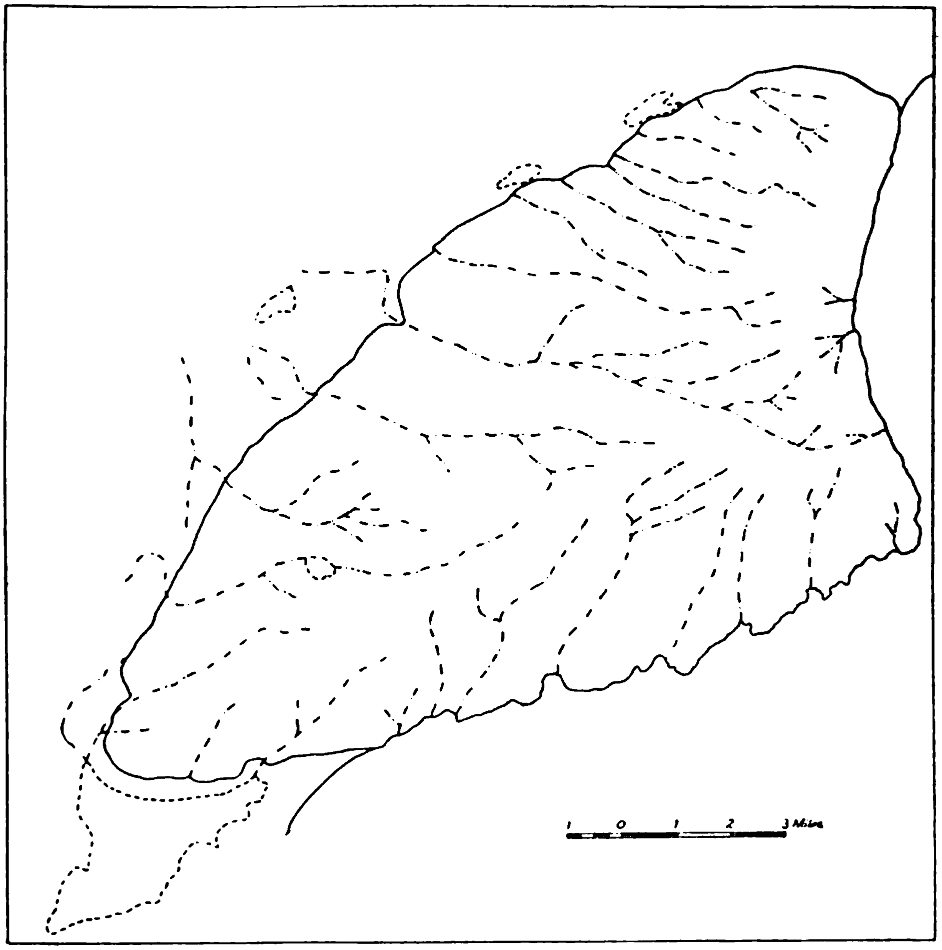

FIGURE 15.—Drainage map of Niihau.

valleys which have been incised into its slopes are shallow, except near their mouths, where they become narrow, almost vertically walled gorges 300 or 400 feet in depth. Because of the general slope of the residual, most of the valleys are directed toward the west (fig. 15). None of consequents

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has been cut into the eastern cliffs, but a considerable number break the continuity of the southern cliffs. The heads of the valleys lie to the west of the east short cliffs, hence none of them was truncated by the engulfment. Separating the valleys are broad tabular interfluves which are somewhat more dissected in their upstream than in their downstream parts (fig. 16). The ends of the divides have been truncated by wave action before the emergence of the reef-covered platform; because of the arid climate, these former shore cliffs have suffered little dissection.

The largest valley (Keanuahi) and one or two of the smaller ones have been alluviated for a short distance from their mouths, but the depth of the alluvial fill is not known. The presence of these deposits indicates that erosion below the present sea level took place; submergence and alluviation followed the return of sea level to its normal position. This may have happened during the changing levels of the Pleistocene oceans.

Coastal Lowland

The coastal lowland, which borders the dome remnant on the north, west, and south, has been formed by the elevation of a broad, wave-cut platform, covered over a considerable part of its area by a thin, fringing reef (fig. 14, *b*). The width of the plain varies from about 3.5 miles at its northern extremity to 1 mile where it borders the highland on the west and from there increases to over 4 miles in its southern portion. In many places, the reef limestone is absent, and the rather rough basaltic surface is exposed. Also, several, small, cliffed residuals, which were islands in the pre-emergence sea, project above the general level of the plain. The most conspicuous of these is a flat-topped eminence, called Kawaewae, 1 mile southeast of Nonopapa. The top of this residual now stands 290 feet above sea level (fig. 14, *a*).

The surface of the plain is gently rolling, except for certain points which stand considerably above the general level. These points either are pre-emergence islands or tuff cones which have been erupted at various places over the plain. The highest of them, 548 feet, forms the southern tip of the island. In addition, there is a low rampart of sand dunes, 25 to 30 feet high, along considerable stretches of the coast line. At certain localities, these sands have been more or less firmly lithified, and low sea cliffs have been cut into them. No valleys cross the lowland; the occasional flow from the highland gorges is quickly absorbed in the porous soils and rarely, if ever, reaches the sea. Shallow basins of large size, apparently initial depressions in the platform surface or in the reef, are filled with water during the rainy season; in the drier months, the waters partially or completely disappear, and the depressions appear as salt flats, underlain by wet, plastic, lateritic clays, most of which are derived from the weathered basalts of the highland.

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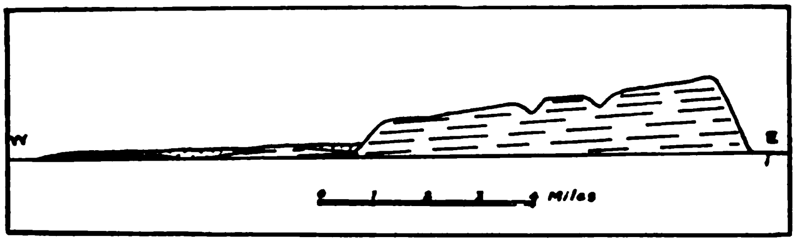
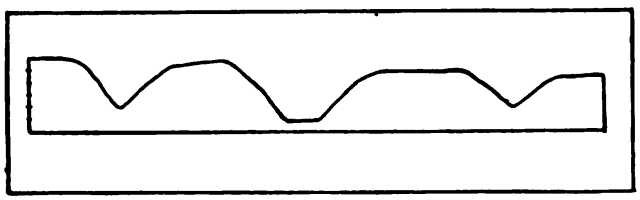
In general, the surface of the plain slopes from the base of the dome remnant to the coast line, but at certain localities low cliffs have been cut either into the lavas of the wave cut platform alone or into the overlying reef and lithified sand dunes as well. The most conspicuously cliffed section is in the vicinity of Kiekie. Along the southeastern coast, low cliffs have been cut into the lithified dunes (Pl. XII, *A*). More than two-thirds of the cinder cone (Kawaihoa) at the southern tip of the island has been destroyed by wave erosion.



a



b

FIGURE 16.—Cross-sections of Niihau. *a*, northeast-southwest cross-section through the island of Niihau. (Vertical scale: 1/10 in. = 200 feet); *b*, valleys and interfluves of the Niihau dome remnant. (Vertical scale: 1 space=100 feet.)

Along the seaward side of Kawaihoa and elsewhere along the coast of Niihau are recently emerged rock terraces standing 4 to 10 feet above sea level. These terraces are similar to those found on most of the other windward Hawaiian islands and are exposed as the result of the Recent 5-meter change of ocean level.

Isolated Tuff Cone

Less than a mile from the northern tip of Niihau is the crescentic island, Lehua, a small, partially eroded tuff cone, having a maximum diameter of about 1 mile and an elevation of 702 feet (fig. 14). About 100 degrees of its circumference on the northern side has been destroyed by wave attack. The lower slopes of the cone have been channelled by narrow, shallow gulches, separated by relatively undissected sections of the constructional surface. That a Recent emergence of the cone has taken place is indicated by a narrow, wave-cut bench. As I was not able to visit the island, the amount of

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change of level was not measured, but it seems to have been considerably more than that which produced the narrow benches about Kauai and Niihau. In the process of elevation, the cone tilted up slightly toward the east.

A second tuff cone, Kaula, lies about 19 miles southwest of Niihau (fig. 12). As described by Palmer (48, pp. 6-10), this cone is built on a platform that finds its origin in the erosion of an original volcano composed of lava. Palmer does not suggest any relationship between the Kaula platform and Niihau, but, that it is a third principal eruptive center of a compound volcano of which Kauai and Niihau are the remaining exposed summit, can scarcely be questioned. Brief accounts of Kaula have also been published by Hitchcock (40), and by Friedlaender (24).

IGNEOUS ROCKS

The Niihau dome remnant is composed of a series of westward dipping lava flows that have been intruded by numerous dikes and sills (fig. 16, *a*).

As on Kauai, the igneous rocks on Niihau are divisible into two series: (1) the main complex, which largely belongs to the principal eruptive period but also includes intrusives of later date; (2) intrusives and extrusives of a Recent volcanic episode. The lavas of the main complex compose the cliffed dome remnant and are exposed at various places over the lowland and along the seacoast. It is possible that the original dome contained a greater variety of petrographic types than are to be found in the existing remnant. The extrusives of the late volcanic episode, tuff cones and lava flows, have been erupted through the reef which overlies the wave-cut platform of west Niihau. Probably the two isolated tuff cones, Lehua and Kaula, also belong to this late episode.

Although the principal rock types are similar megascopically to those of Kauai, the microscope shows that most of them contain more feldspar and less olivine. The four field groups of olivine basalts differentiated on Kauai also are present on Niihau, but their relative importance is different. Coarse-grained plagioclasic chrysophyres (Field group 1) are the dominant lavas; the fine-grained chrysophyres (Field group 2) the chief type of olivine basalt on Kauai, are somewhat less abundant. The lavas of Field group 3 and nephelite basalts, which were found on Kauai, were not obtained from Niihau, though a more thorough search may reveal their presence. A single specimen of nepheline melilite basalt was obtained from a flow belonging to the main complex (34, pp. 534-35).

The flows of the main igneous complex are cut by great number of porphyritic and trappean dikes and sills composed chiefly of olivine basalt and olivine-poor or olivine-free augite andesite. A few diabasic dikes also were found. No coarsely granular plutonic rocks or xenoliths were found.

The lavas of the late episode consist of flows and pyroclastics erupted

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through the fringing reef on the western side of the island. Some of the dikes and sills cutting the main complex doubtless belong to this series. In the tuff cone (Kawaihoa) fragments of the coral reef are embedded.

Chemical analysis of lavas from Niihau are given in Table 9.

SEDIMENTARY ROCKS

The sedimentary rocks on Niihau are principally on the lowland, but small deposits are present in some of the highland gorges. They include (1) fringing reefs; (2) beach sediments; (3) sand dunes; and (4) alluvial deposits.

1. Much of the elevated wave cut platform is covered by a fringing reef which in few places exceeds 100 feet in thickness. Over considerable sections of the platform, the reef is absent. Most of the reef and the basaltic surface, where exposed, is covered by thin layers of sediments, the greater part of which has been brought down by streams from the highland. Along the coast, the mantle is chiefly of calcareous sand, with which is mixed small quantities of basaltic detritus. So far as could be ascertained, no living reef is present about Niihau. The last volcanic episode occurred after the growth of most or all of the reef. Fragments of reef limestone in some of the tuff cones, and deposits of ejecta overlying the reef duplicate the relations found in Kauai. Reef limestone fragments have been reported also from Kaula.

2. The beach sediments are composed of basaltic and calcareous débris; the dominant constituent varies from place to place.

3. Ramparts of calcareous sand dunes, few of them more than 30 feet in height, are present at many places along the shore, and, at certain localities, moderately thick deposits of sand have been drifted inland close to the base of the dome remnant. The principal areas of lithified dunes is along the southeastern (Kona) coast (Pl. XI, *B*).

The fossils in the following list were obtained from sand dunes near Kii (column 1); from partially lithified dunes near Cape Kawaihoa (column 2); from sand dunes at the south end of the basalt cliffs (column 3); from sand dunes south of Kii (column 4); from a beach on the southeast coast (column 5); and from a beach east of Kawaewae (column 6). The species were identified by Professor Junius Henderson.

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	1	2	3	4	5	6	7
Podophera pedifera	—	—	—	—	—	X	—
Echinoid spines	X	—	—	—	—	—	—
Chama sp.	—	—	—	—	X	—	—
Codakia ramulosa Gould	—	—	—	—	X	—	—
Perna sp.	—	—	—	—	X	—	—
Venus reticulatus Linneaus	—	—	X	—	X	—	—
Conus hebraeus Linneaus	—	—	X	—	X	—	—
Conus lividus Hwass	—	—	X	X	X	X	—
Cypra caput-serpentis Linnaeus	—	—	X	—	X	X	X
Cypra isabella Linnaeus	—	—	—	—	X	X	—
Cypra madagascarensis Gmelin	—	—	—	—	X	—	—
Cypra mauritiana Linnaeus	X	—	X	—	—	—	—
Cypra reticulata Martyn	X	—	X	—	X	—	—
Eulima sp.	—	—	—	—	X	—	—
Glyphis granifera Pease	—	—	—	—	X	—	—
Helcioniscus argentatus Sowerby	X	—	X	X	X	—	—
Helcioniscus exaratus Nuttall	X	X	X	X	X	X	X
Hipponyx antiquatus Linnaeus	—	—	—	—	X	—	—
Hipponyx cf. barbatus Sowerby	—	—	—	—	X	—	—
Littorina pintado Wood	—	X	X	—	—	X	—
Nerita picea Recluz	X	X	X	X	X	—	X
Nerita polita Linnaeus	X	—	X	X	—	—	X
Patella sp.	—	X	X	—	X	X	—
Vermetus sp.	—	—	—	—	X	X	—
Purpura aperta Blainville	X	X	X	X	—	—	X
Ricinula ricinus Linnaeus	X	—	X	—	—	X	—
Sistrum tuberculatum Blainville	X	—	—	—	—	—	—
Strombus maculatus Nuttall	X	—	—	—	—	—	—
Terebra strigilata Linnaeus	—	—	X	—	—	—	—
Turbo chrysostomus Linnaeus	X	—	—	X	—	—	X

4. Alluvial Deposits. Of the alluvial deposits, the alluvio-lacustrine sediments on the reef and platform surface are the most worthy of consideration. A number of large, shallow depressions are present in the reef and platform; these in the wet seasons are filled with shallow depths of water. (See p. 95.) Because of the abundant migration of sea water through the porous reef limestone or through the underlying porous and cavernous lavas, the water in the depressions quickly becomes distinctly brackish, and, after the rainy season ends, turns saline upon some evaporation. The depressions are floored with reddish, lateritic clays evidently transported from the highland by wind and by the occasional streams which flow through the valleys. The red clay is abundantly mixed with salt which crystallizes out as the waters disappear; this is specially noticeable during the long dry spells to which the island is rather frequently subject. During the dry periods, the clay hardens and cracks at the surface, but remains wet and plastic below, so that travelling across the flats is dangerous because of the chance of breaking through the crust and becoming mired in the rather deep muds underneath. Cattle and sheep are not infrequently lost in this way.

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EVIDENCES OF CHANGES OF LEVEL

The changes of level recorded on Niihau are: the elevation of the wide, wave-cut platform with its thin cover of reef, and the Recent slight emergence of narrow rock terraces.

The elevation of the platform at the base of the dome remnant is about 50 feet. Residuals, which were islands in the pre-emergence sea, rise to a maximum of 290 feet. The vertical movement indicated by the emergence of the platform is 65 to 70 feet. Certain poorly developed terraces cut into the platform indicate that the elevation was interrupted by short periods of still stand. The major change of level recorded on Niihau appears to have been considerably less than on Kauai, where an upward movement of over 500 feet took place. The two movements were not contemporaneous, and the Kauai platform probably was elevated first. No reef is present on the Kauai structure, and into it numerous gorges have been cut. The Niihau bench, on the other hand, has a reef coating, and is virtually undissected by streams. The topographic difference, however, may have resulted from the much greater rainfall over Kauai. Judging from the amount of dissection of the Kauai platform, its emergence must have taken place well back in the Pleistocene at the time of the faulting which broke the Kauai-Niihau volcano in two. The elevation of Niihau took place without tilting, and apparently occurred at a much later date. If the Hawaiian reefs are late Glacial or post-Glacial in age, then Niihau was elevated in late Pleistocene or Recent times.

The Recent 16-foot change of ocean level is recorded on Niihau at many places by rock benches which stand from from 4 to 5 to 8 or 10 feet above mean sea level.

FAULTING

The only positive evidence of faulting on Niihau is that which resulted in the engulfment of the eastern half of the dome. The rift zone lies about 2 miles east of the present eastern shore of the island. Since this dislocation took place, Kauai and Niihau have behaved as more or less distinct units.

THE AGE OF NIIHAU LANDSCAPE

The relative ages of the Kauai and Niihau landscapes are difficult to ascertain. On the doublet island of Oahu, Maui, and Molokai, the western member is the older; if this order of extinction of the last principal eruptive period can be applied to the Kauai-Niihau volcano, Niihau is the older of the two. The third principal eruptive center of the same volcano indicated by the platform underlying Kaula to the southwest of Niihau became extinct at a still earlier period. Niihau seems to occupy an intermediate stage in the

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postvolcanic history of lava domes between Kauai and the third, submerged center.

The width of the elevated, wave-cut platform on Niihau suggests a long period of erosion, and erosion when the waves were much more active about the leeward shores of the island than they are at the present time. If changed climatic conditions prevailed in the latitudes of the Hawaiian Archipelago during the glacial stages of the Pleistocene, then such features as this platform, the great western cliffs of Kauai and other islands can be more easily accounted for. The last major eruptive cycle on Niihau therefore appears to have closed well back in the Pleistocene or more probably in the Pliocene. Topographic comparisons with Kauai are difficult because of the strongly contrasted climatic conditions over the two islands which has made the topographic evolution very different. On Niihau, marine erosion has been more effective than fluvial, while, on Kauai, the fluvial exceeds marine. Elevated, wave-cut platforms of considerable width are present on western Niihau and eastern Kauai. A deeply submerged platform on the western side of Kauai is indicated by borings, but nothing is known of its width. Kauai has suffered much greater dissections by streams than has Niihau.

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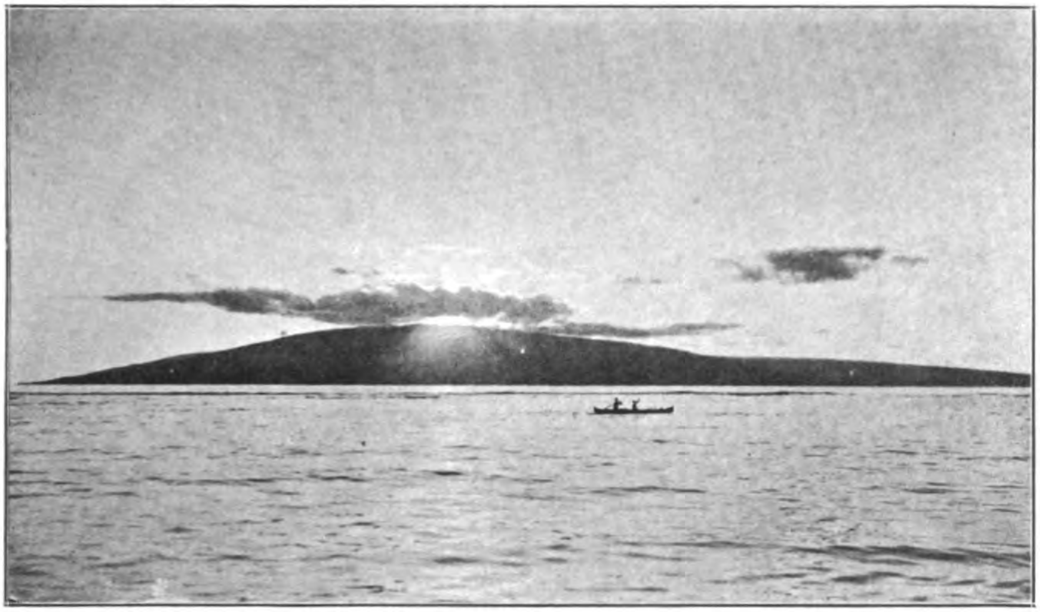

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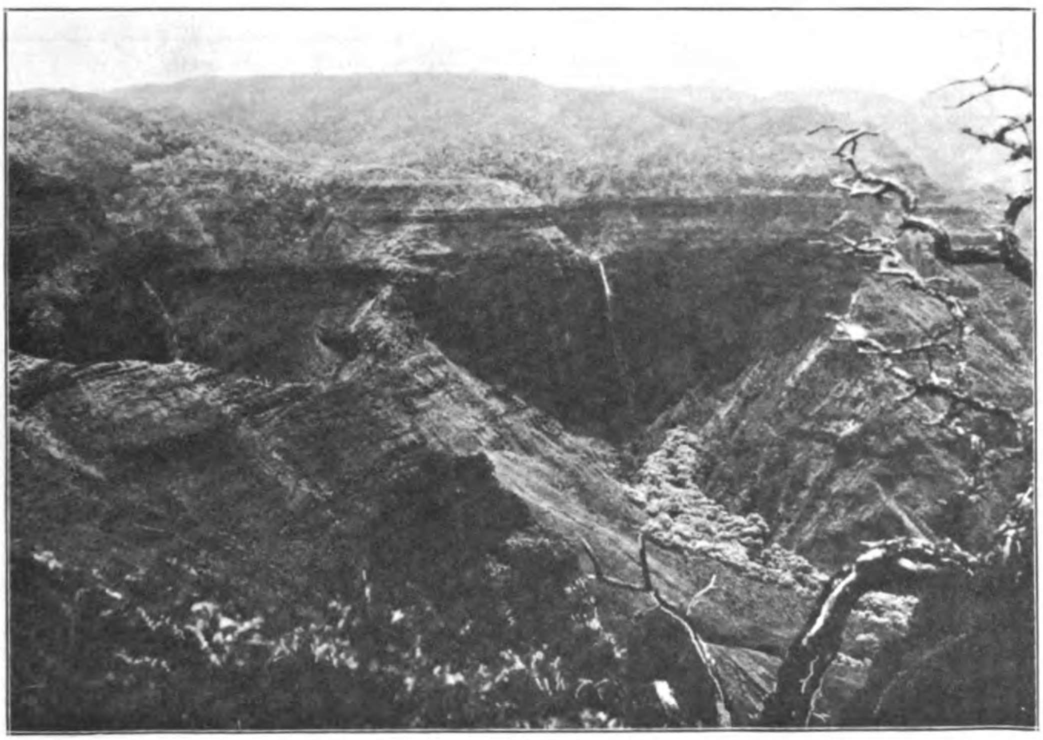

B

A, ISLAND OF LANAI (PHOTOGRAPH BY R. J. BAKER); *B*, WAIMEA CANYON, SOUTHERN KAUAI.

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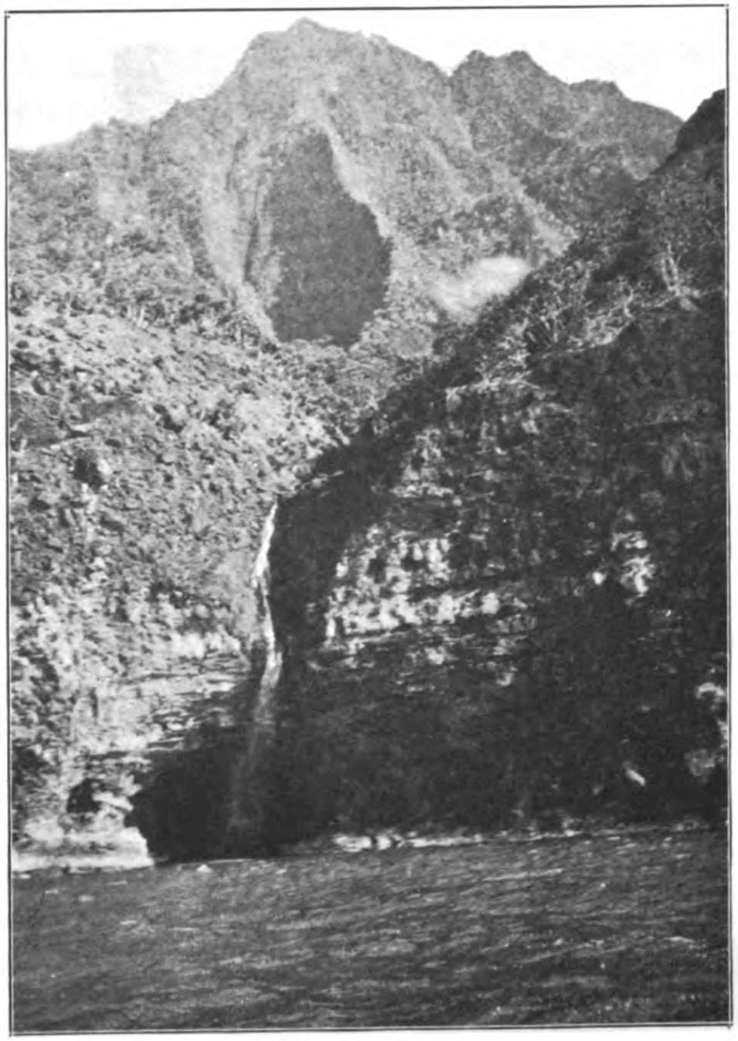

A

B

A, HANGING VALLEY ALONG THE CLIFFED COAST OF NORTHWESTERN KAUAI; *B*, DISCORDANT JUNCTION OF TRIBUTARY AND THE MAIN STREAM, HANAPEPE CANYON.

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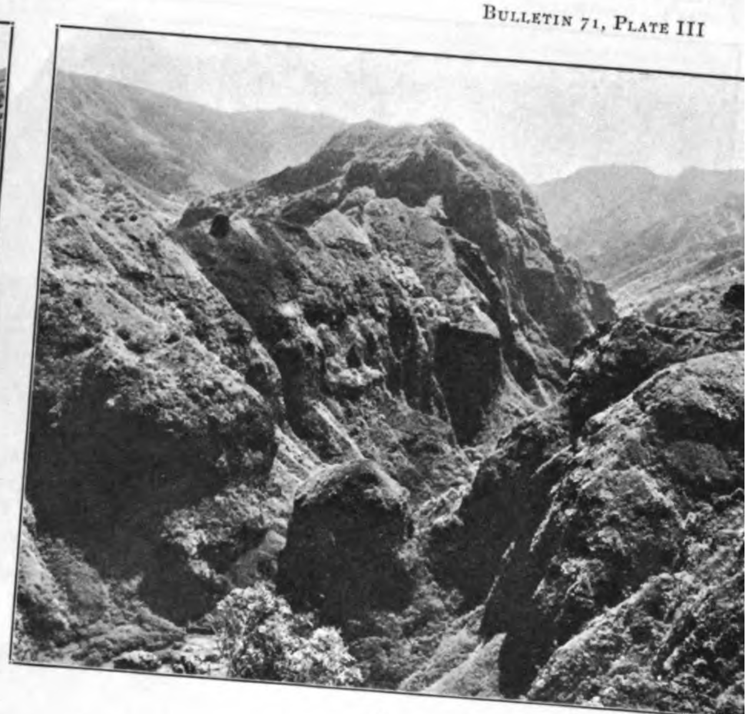

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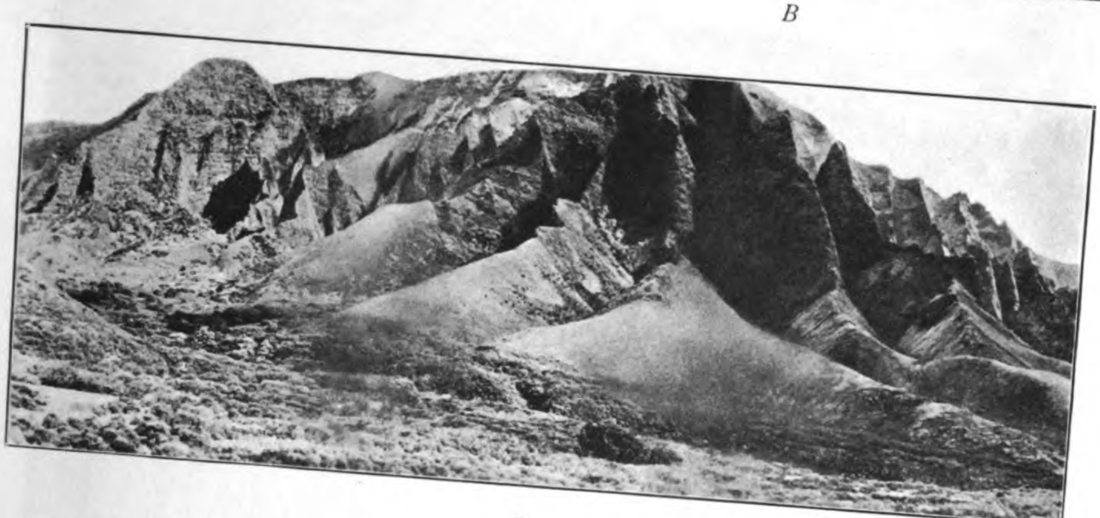

C

A, LOWER PORTION OF OLOKELE CANYON; *B*, VIEW OF THE DISSECTED HIGHLAND OF SOUTHERN KAUAI (PHOTOGRAPH BY O. S. EMERSON); *C*, PANORAMIC VIEW OF KOLALAU CANYON OF NORTHWESTERN KAUAI (PHOTOGRAPH BY O. S. EMERSON).

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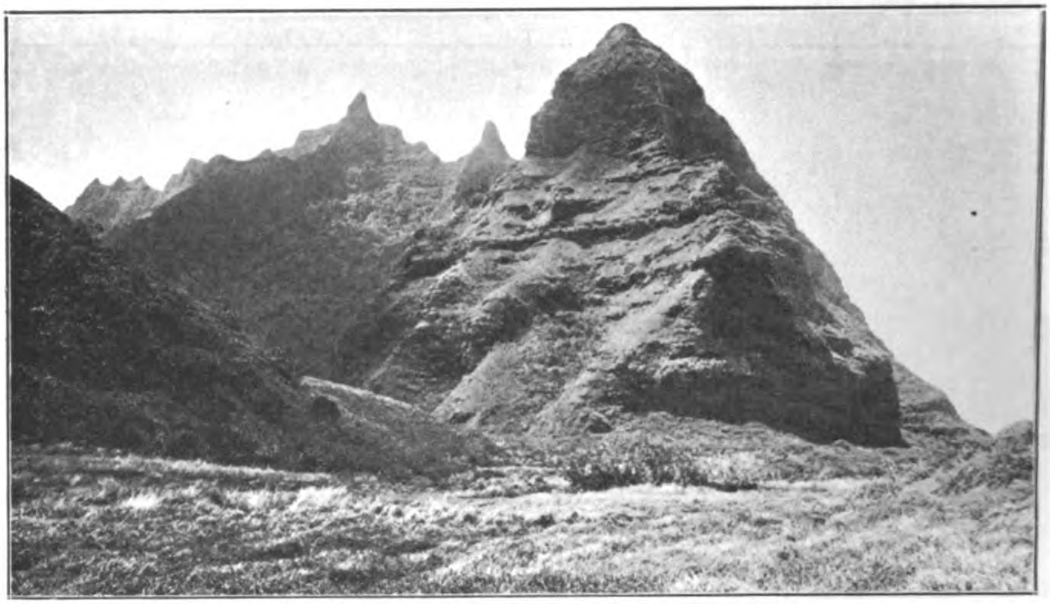

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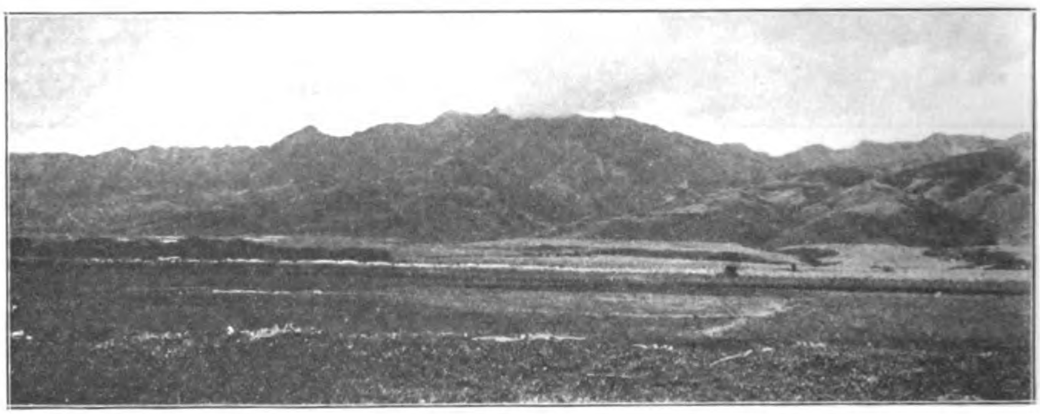

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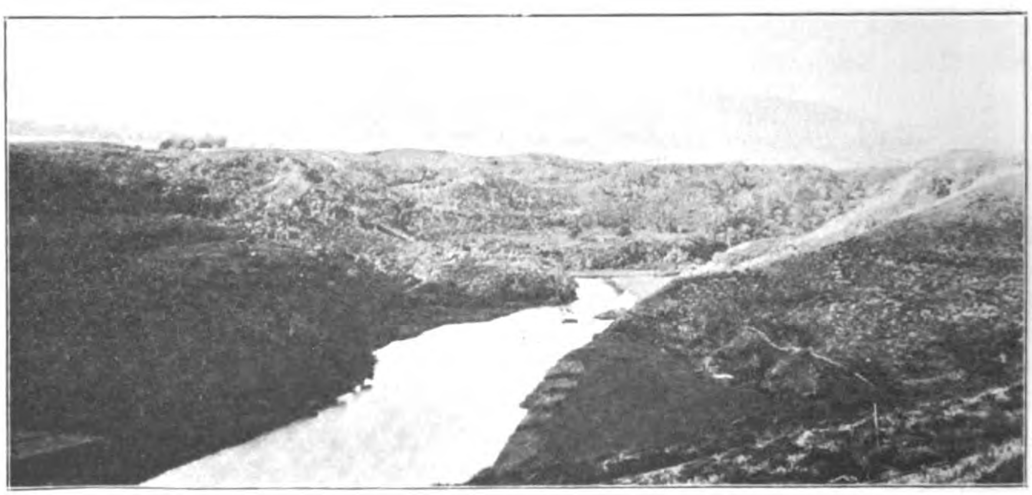

C

A, TERMINUS OF A SHARPLY SERRATED RIDGE IN THE DISSECTED HIGHLAND OF NORTHERN KAUAI; *B*, DISSECTED, WAVE-FACETTED SPURS ALONG THE INNER MARGIN OF THE EMERGED MARINE PLATFORM, NORTHERN KAUAI (PHOTOGRAPH BY R. J. BAKER); *C*, YOUNG GORGE CUT BY SOUTH FORK OF WAILUA RIVER CROSSING THE EMERGED MARINE PLATFORM OF EASTERN KAUAI.

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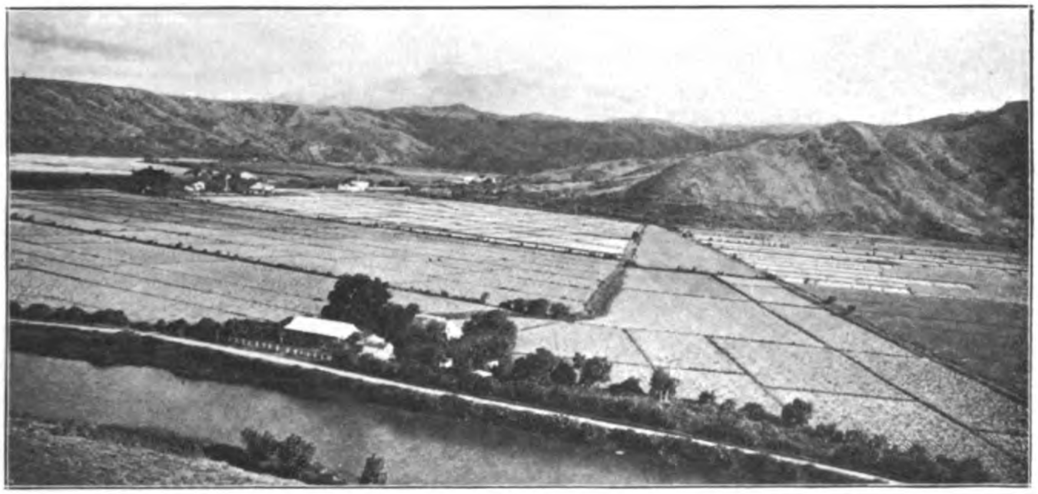

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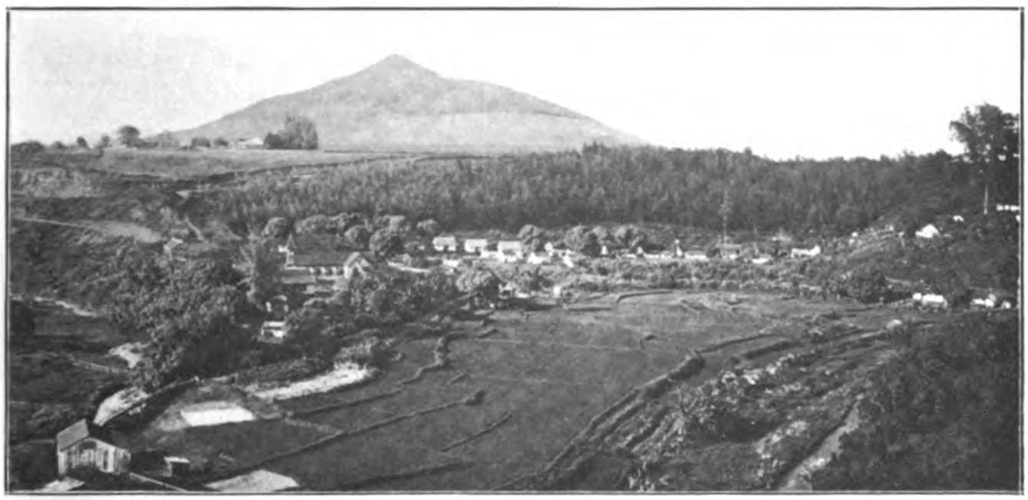

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C

A, THE ALLUVIATED FLOOR OF HANALEI RIVER; *B*, HANAMAULU VALLEY, AN ALLUVIATED GORGE ERODED INTO THE MARINE PLATFORM OF EASTERN KAUAI; *C*, TUFF CONE (KILOHANO) ERUPTED ON THE MARINE PLATFORM OF EASTERN KAUAI (PHOTOGRAPHS BY R. J. BAKER).

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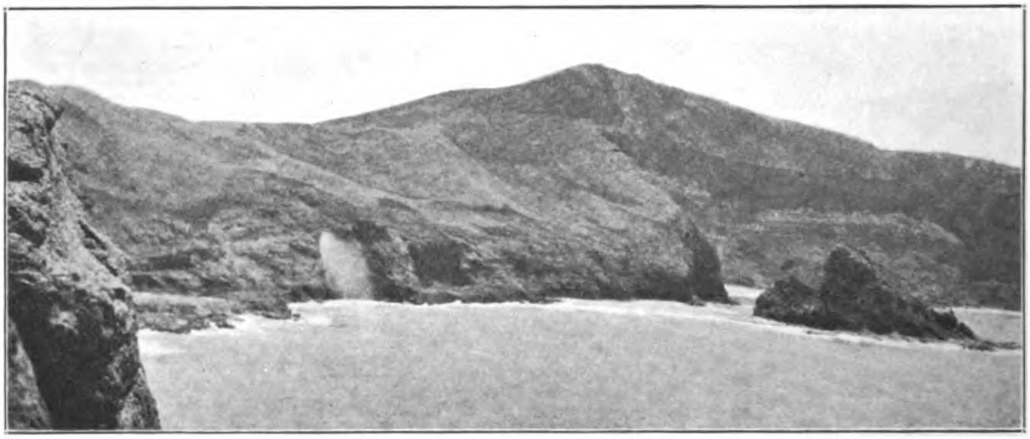

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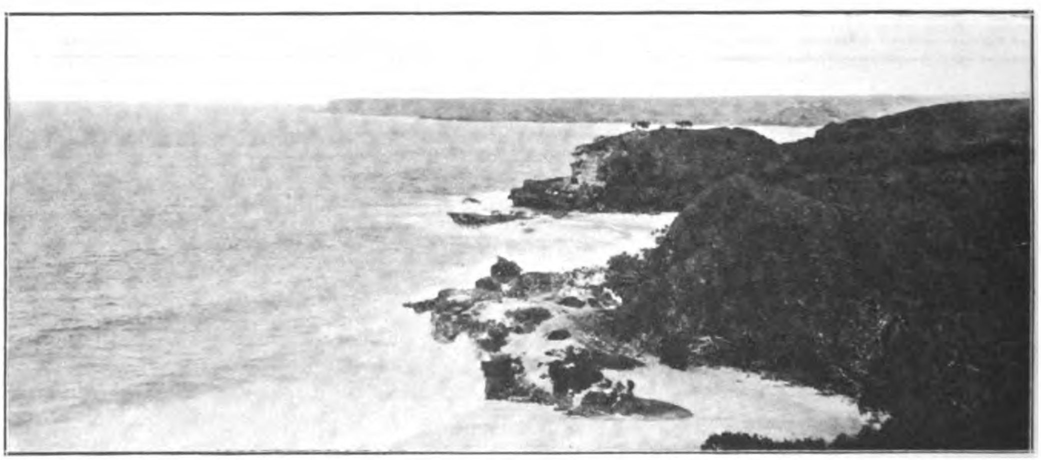

C

A, SHOREWARD SIDE OF THE DISSECTED TUFF CONE AT KILAUEA BAY; *B*, COASTAL MARGIN OF THE CONSTRUCTIONAL, HINTER-REEF PLAIN OF NORTHERN KAUAI; *C*, SEAWARD SLOPING, EMERGED MARINE PLATFORM NEAR MOUTH OF KALIHIWAI STREAM (PHOTOGRAPH BY SENDA).

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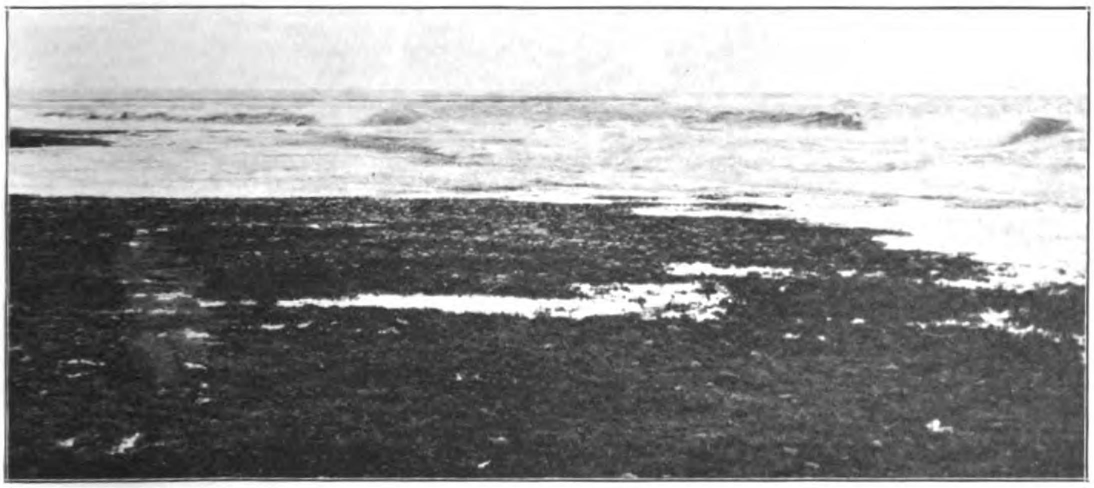

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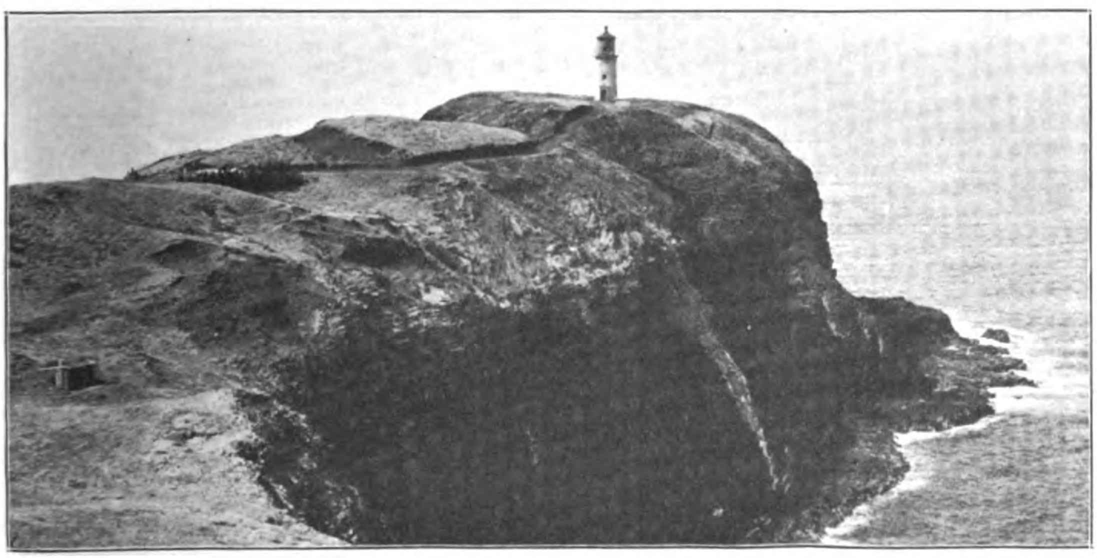

C

A, RAMPART OF SAND DUNES ALONG THE OUTER MARGIN OF THE HINTER-REEF PLAIN, NORTHERN KAUAI; *B*, FRINGING REEF, NORTHERN KAUAI; SEA CLIFFS ERODED INTO THE EMERGED, WAVE-CUT, PLATFORM OF NORTHERN KAUAI (PHOTOGRAPH BY SENDA).

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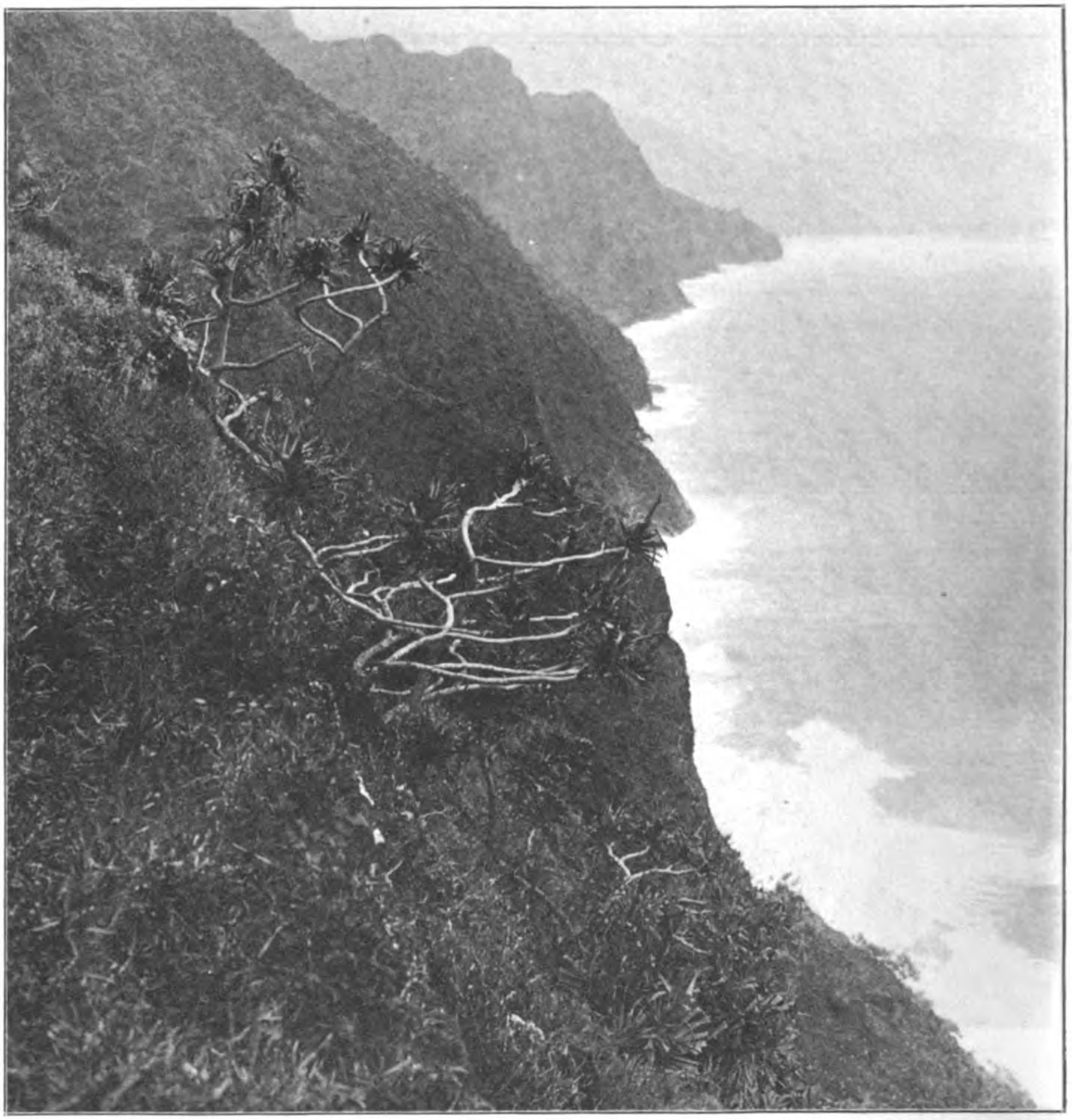

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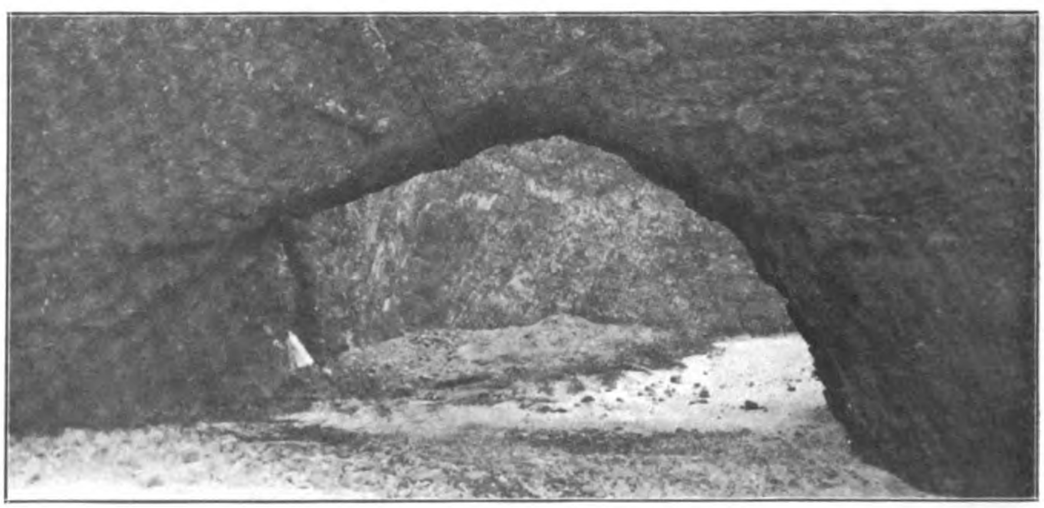

B

A, DISSECTED, RECENTLY NIPPED CLIFFS FORMING THE NORTHWESTERN (NAPALI) COAST OF KAUAI (PHOTOGRAPH BY R. J. BAKER); *B*, WAVE-CUT TUNNEL THROUGH A NARROW HEADLAND OF THE NORTHWESTERN (NAPALI) COAST OF KAUAI.

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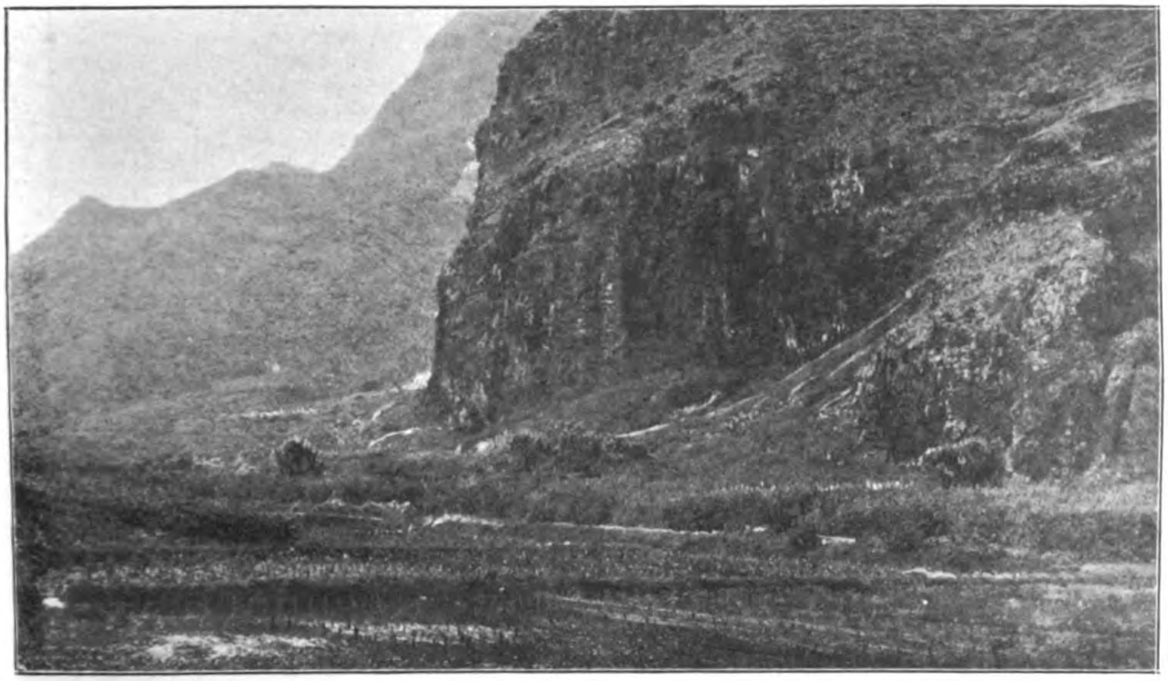

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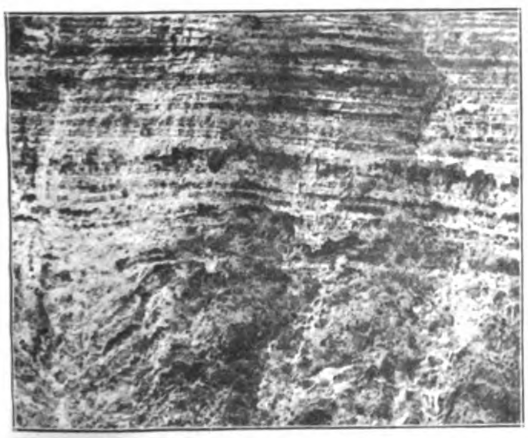

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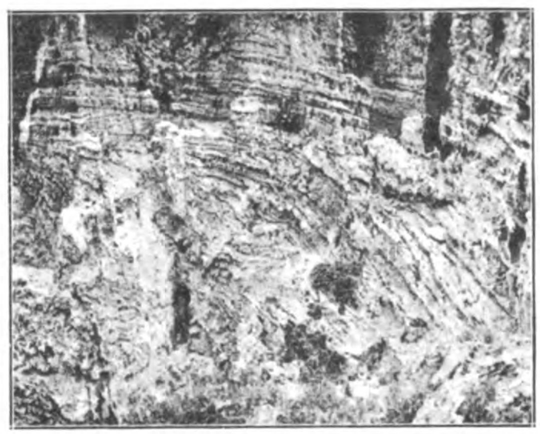

C

A, INNER MARGIN OF THE CONSTRUCTIONAL HINTER-REEF PLAIN OF NORTHERN KAUAI; *B*, *C*, STRUCTURES IN LITHIFIED SAND DUNES, SOUTHERN COAST OF KAUAI.

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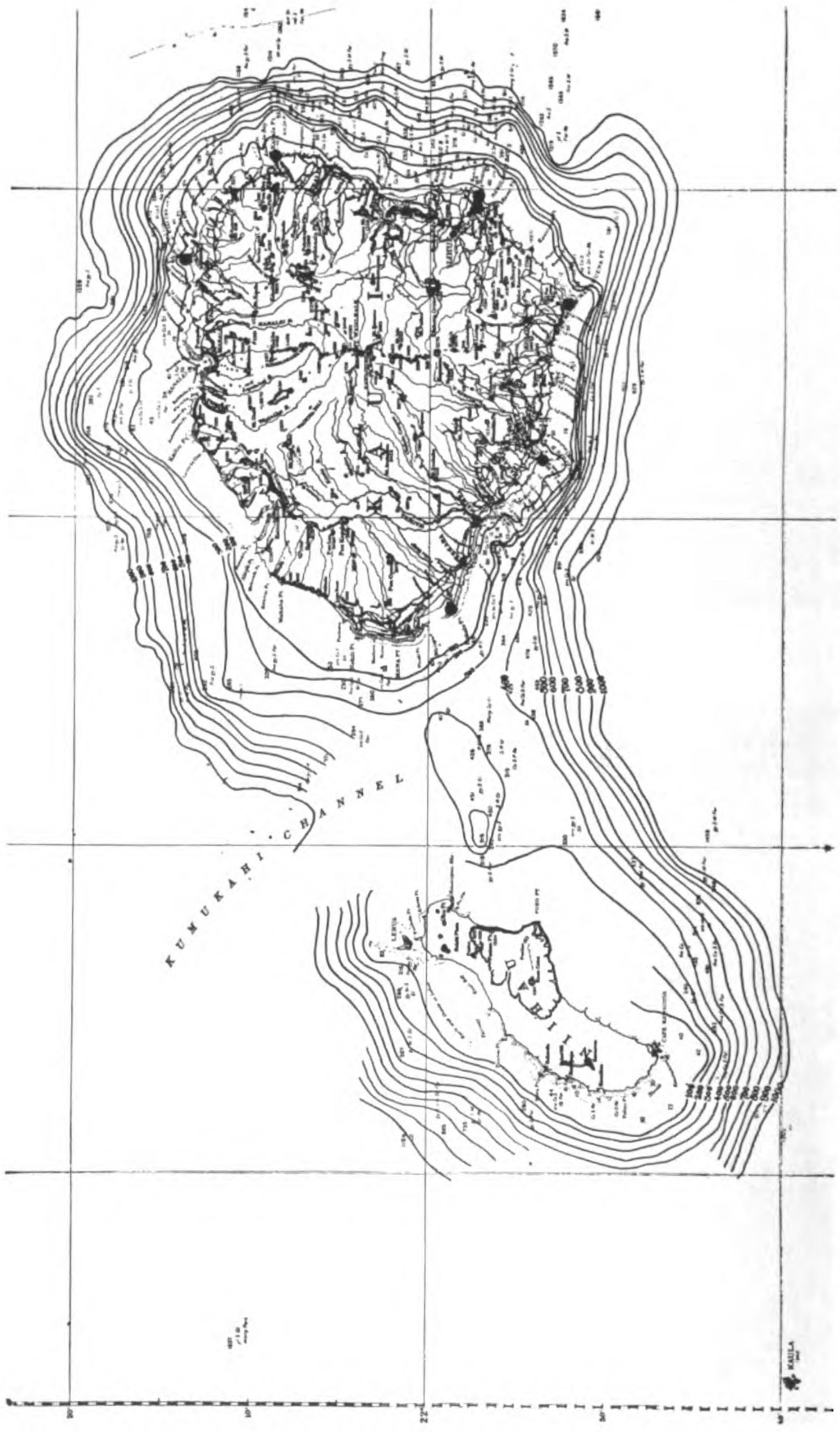

KAUAI-NIIHAU VOLCANO, SUBMARINE CONTOURS 100-FATHOMS. DATA FROM COAST AND GEODETIC SURVEY.

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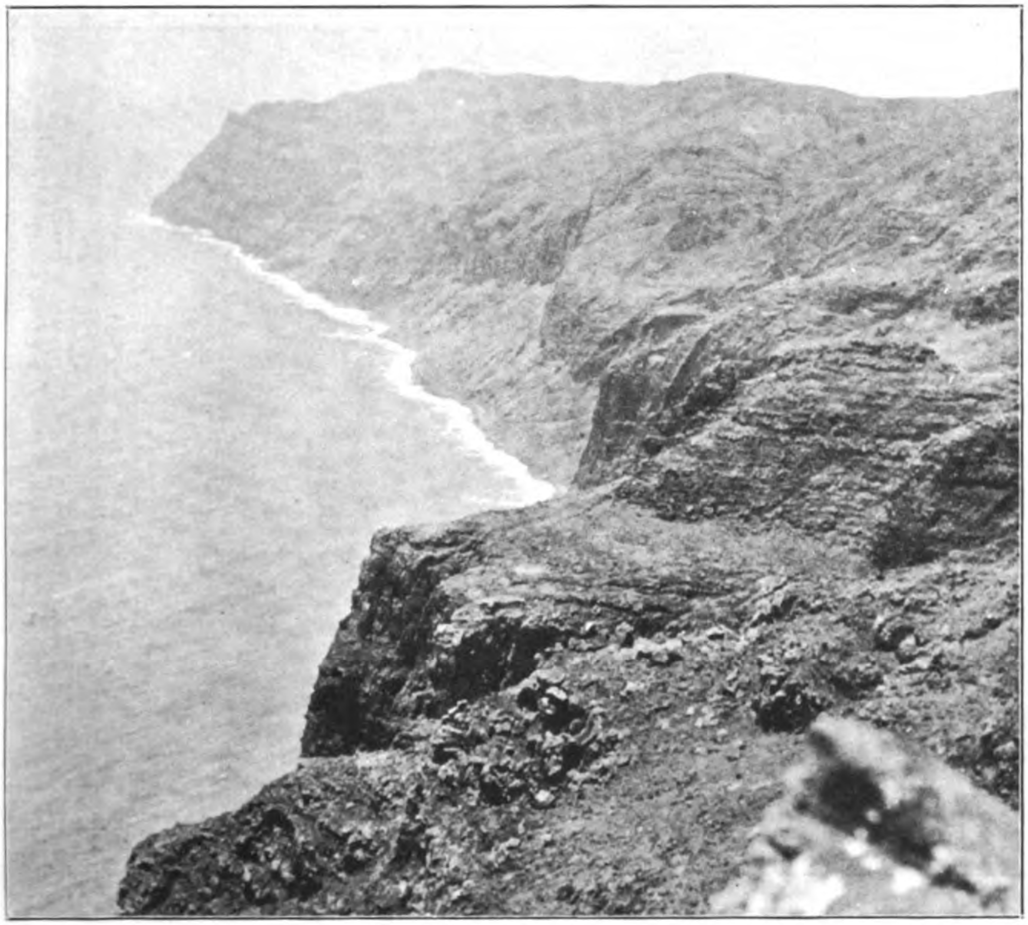

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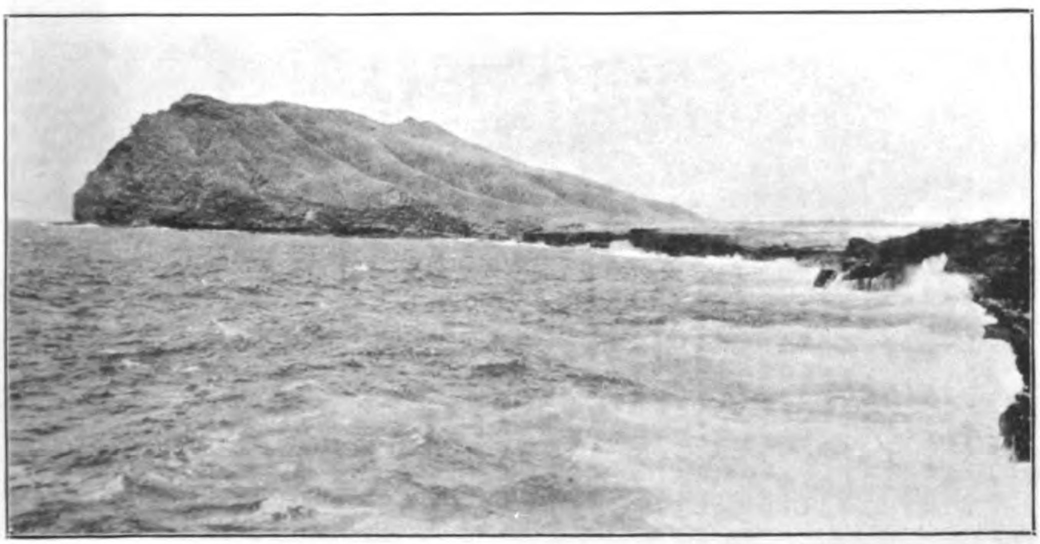

B

A, FAULT LINE, SCARP FORMING THE EASTERN FACE OF THE NIIHAU LAVA DOME REMNANT; *B*, DISSECTED TUFF CONE (KAWAIHOA), SOUTHERN END OF NIIHAU.

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A

B

A, THE EMERGED, REEF-COVERED PLAIN OF SOUTHERN NIIHAU; *B*, GENERAL VIEW OF THE NIIHAU DOME REMNANT.

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GEOLOGY OF RAROTONGA AND ATIU

BY

PATRICK MARSHALL

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Geology of Rarotonga and Atiu

By

Patrick Marshall

THE COOK ISLANDS

INTRODUCTION

The observations here recorded were made during a visit to Rarotonga and Atiu islands in May and June, 1926, as a Bishop Museum Fellow in Yale University. Most generous assistance was given by Sir Maui Pomare, Minister for the Cook Islands in the New Zealand Cabinet. At Rarotonga Judge F. L. Ayson, Resident Commissioner for the Cook Islands, gave every facility and help. I am particularly indebted to Mr. W. H. Scott, Resident Agent for Atiu Island, and Mrs. Scott who entertained me with the most kindly and generous hospitality, and arranged for work with the natives. Owing to Mr. Scott's influence the services of a most suitable guide, Ngapaku, a grandson of the famous Rongomatane, were enlisted.

GEOGRAPHIC SKETCH

The archipelago of Cook Islands, named for Captain James Cook, lies between 18° and 22° south latitude and 157° and 160° west longitude. It comprises six small islands—Rarotonga, Mangaia, Mauke, Mitiaro, Atiu, Takutea, Manuae, and Aitutaki. Rarotonga, the largest and by far the most lofty, is about 20 miles in circumference and its highest peak reaches 2100 feet above sea. The summit altitude of Mangaia is 550 feet; of Aitutaki, 450 feet; of Atiu, 270 feet; of Mauke, 100 feet; of Mitiaro, 90 feet. Manuae is an atoll and Takutea merely a sandbank, not more than 20 feet above high water. All of the islands are surrounded by coral reefs. Aitutaki has a barrier reef which in places is 4 miles distant from the shore, but in all of the southern islands the reefs are merely fringing. (See fig. 1.)

The vegetation of Cook Islands is most abundant and most varied on Rarotonga. (See p. 14.) On all the islands the plants of the coastal strip are the same; *Barringtonia* is dominant over *Pandanus* and *Casuarina* and the more lowly forms. In the Makatea *Alcurites* is everywhere conspicuous as well as banyan and orange trees; *Elaeocarpus* is also present. In the water-courses and on the margins of the swamps the "chestnut" *(Inocarpus)* is abundant. The volcanic ground in Mangaia and Atiu is covered with a native *Gleichenia* and a few *Casuarina* trees scattered here and there, and all the

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valleys present a varied flora. The coconut is the only native palm tree of the Cook Islands except for the island of Mitiaro where Gill (15) reports a palm similar to those on Niue and Vavau. The native banana (*Musa fehi*) is not plentiful in Mangaia and is rare in Atiu but it is cultivated at Aitutaki. The guava has spread over much of the volcanic ground in both Mangaia and Atiu and grows in great luxuriance in Aitutaki.

Animal life is poorly represented in Cook Islands. The only indigenous mammal is a rat. There are a few lizards but no snakes and no native frogs.

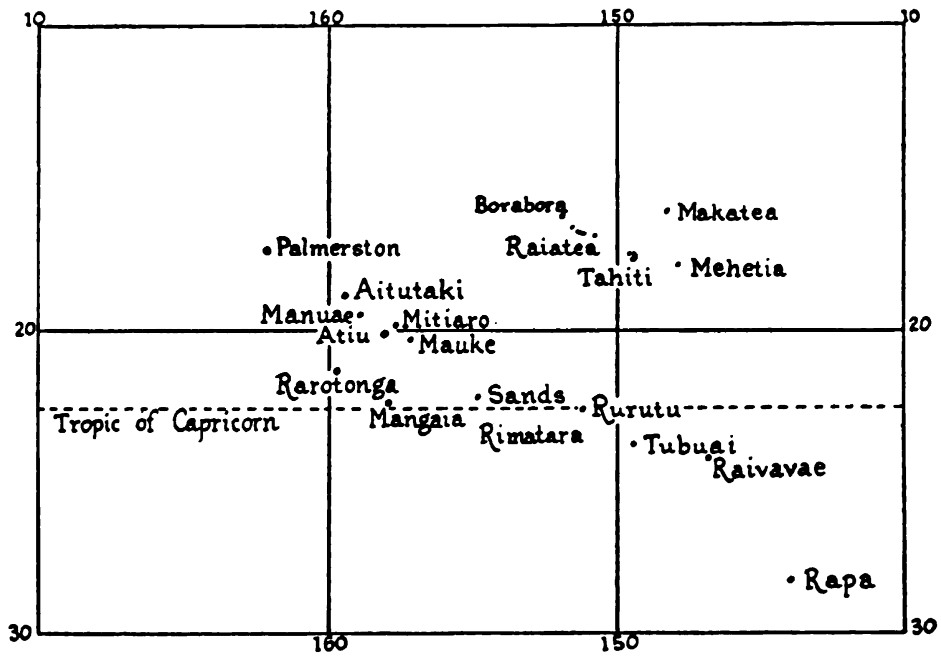

FIGURE 1.—Index map showing Cook Islands, Society Islands, Austral Islands, and Rapa Island.

Land birds are now scarce. In Rarotonga few are to be seen though the plaintive coo of one of the two native kinds of dove is often heard. Two other small birds are occasionally seen. In Mangaia a kingfisher is very common near the coast and in Atiu a small swallow is always hunting insects in the evening. The frigate bird is the largest of the sea birds but it is seldom seen in most of the islands. The "bosun bird" or tropic bird (*Phaethon*) is common in Rarotonga where it nests in some of the inaccessible cliffs. The red tailed species nests on Takutea Island. In all the islands two or three kinds of petrels are to be found and the New Zealand duck (*Anas superciliosa*) is not uncommon.

The natives of Cook Islands are typical Polynesians though of rather shorter stature and perhaps a little more darkly colored than the Maoris. Their language is nearly identical with that of the Maoris and it is noticeable

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that the consonants *k* and *ng* are not dropped as in the Tahitian dialect. In manner the Cook Islanders are less noisy and truculent but in general their customs and habits are similar to those of the Maoris. They recognize the same system of deities or spirits pervading natural objects.

Rank among the natives is hereditary. The most important men are the *ariki* who can trace their lineage back to a time before their forefathers arrived in Cook Islands. Subordinate chiefs are *mataiopo* who have authority over small districts. The *rangatira* are inferior to them but still have a considerable standing. The rest of the people are referred to as *ui tangata*. At the present day respect and deference to rank and authority which were previously recognized without question have almost disappeared.

The houses of the native people were oblong with walls about 7 feet high, constructed of straight sticks of hau (*au, purau, Hibiscus*) fastened to horizontal bars at the top and bottom. Though these uprights were close together, air passed between them freely. A number of rafters extended from the top of the walls sloping to the ridgepole. Saplings were fixed across the rafters at intervals. On these the thatching of lauhala (*ara, Pandanus* leaves) was placed and fastened. The houses were provided with a doorway and a small window space at one end. There was neither flooring nor partitions. All the native houses were small and distributed generally through the islands. After the missionaries had instructed the people in the various arts of civilization it became the fashion to build the houses of concrete. What was gained in solidity and privacy was lost in ventilation and coolness. There is now a tendency among the natives to revert to the former type of construction.

Each native family held title to a certain portion of land originally granted by the *ariki* of his district. The land had the form of a *tapere,* an area with a base on the coast and with sides which converged to the central point of the island or district. The head of the family could divide this up among his people or dependents in any way that pleased him. In several of the islands these family estates and even individual holdings have now been accurately defined by surveyors. Land cannot now be bought by Europeans and it is difficult to lease any land.

The natives grow taro, breadfruit, kumera, yam, and coconut. Some fish are caught, shellfish are gathered on the reef, and some pigs are raised by feeding them coconuts and other vegetable products. There are also some domestic fowls. The natives have now acquired a liking for canned meats and for biscuits and other articles made of flour. The means for purchasing these are obtained by the sale of copra, oranges, bananas, and tomatoes, which are supplied to the New Zealand market. The preference for European food and the demand for European dress material, which has entirely superseded the old tapa or bark cloth, has caused the natives to become more

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industrious but the area of land which has come into cultivation, though considerable, is still far less than that at the time when the islands were first visited by the missionaries. Recently picture shows and motor cars have given additional incentive to industry.

The ordinary trade of the Cook Islands is based entirely on vegetable products. Copra, which ranks first in value is exported mostly to Europe. Oranges and tomatoes are sent in considerable quantity from Rarotonga to New Zealand and from the other islands oranges are occasionally shipped. The money that is obtained from this trade is spent in buying dress goods, tinned beef, tools, and vehicles. The picture theatre in Rarotonga calls for considerable expenditure.

A considerable number of natives of Mangaia and Atiu live in Rarotonga where it is easier to obtain paid work and where the mail steamers which anchor off the island every four weeks bring customers for the island products. There are also settlements of Cook Islanders in Tahiti.

The discouragement that is given to alien ownership of land in Cook Islands has naturally prevented Europeans from settling in large numbers. The native population seems to be much smaller than at the time when the islands were discovered by the early voyagers and missionaries. Of late years, however, there has been a slight increase. The census of 1925 gave the following figures:

	RAROTONGA	AITUTAKI	MANGAIA	ATIU	MAUKE	MITIARO	TOTAL
Polynesians	3,713	1,418	1,233	923	506	236	8,029
Europeans	192	15	16	10	5	2	240
Total	3,905	1,433	1,249	933	511	238	8,269

When discovered by Europeans, each of the Cook Islands was governed by a chief, always a man of ancient lineage, who exercised despotic power over life and land. Afterwards missionaries working in conjunction with the chiefs caused the enactment of a code of laws which in some of its details now seems laughable. At a later time Ariki's courts and a federal parliament were established. For many years Cook Islands was a protectorate of Great Britain but in 1900 the group was annexed by New Zealand. A Resident Commissioner living in Rarotonga is responsible for the administration of all the islands and is President of the high court. (See New Zealand Year Book for 1907.) In each of the other islands the Government is represented by a resident agent. There is a hospital in Rarotonga and nurses in charge of dispensaries in the other islands. Education is compulsory and all instruction is in English.

GEOLOGIC FEATURES

The general geology of Cook Islands is simple. Rarotonga is formed of volcanic rock with a fringe of raised coral only 15 to 20 feet above high water.

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On Atiu the raised coral rock stands 70 feet above sea and the volcanic material is relatively small in amount. On Mangaia the raised coral rock—Miocene in age—attains a height of 200 feet but the volcanic material is much less extensive than in Rarotonga. Mauke has very little volcanic rock and the height of the raised coral is perhaps 100 feet, though accurate measurements are lacking. Mitiaro has no volcanic ground but the center of the island, where from analogy with Mangaia and Atiu, volcanic rock would be expected, is occupied by a lake. Manuae is an atoll and Takutea merely marks the site of a coral reef. Aitutaki has a small island of volcanic rock in the corner of a barrier reef some eight miles in diameter.

REGIONAL GEOLOGIC RELATIONS

The altitude of the coral rock on the different islands suggests that so far as the latest movements are concerned a neutral line of movement extends from a point close to the northern shore of Rarotonga in a northeast direction and passes between Atiu and Manuae islands. Whether the effect of such a movement extended beyond the limits of the Cook Islands cannot be stated. For the islands lying southeast of Mangaia information is available only for Rurutu and Rapa. It is, however, noticeable that Palmerston Island, 200 miles west-northwest of Aitutaki, is an atoll. On the northern side of this neutral line there has been a depression and on the southern side an elevation. The upward movement seems to have increased with the distance from the neutral line but the amount of depression is unknown—downward movements in oceanic islands are registered less clearly than upward ones. There is no indication that this movement was associated with rock folding.

The relation between the Cook Islands and other island groups in the South Pacific is not clear. It is not certainly known whether the different islands arise from one plateau or whether they are the emergent peaks of a submarine ridge, as their somewhat linear arrangement suggests. The only soundings given in the British Admiralty chart are one of 2,498 fathoms 120 miles west of Aitutaki, one of 2,632 a hundred miles still further west, and one of 2,740 fathoms about 200 miles southwest of Rarotonga. These few soundings merely indicate that there is deep water around the islands. There are no soundings recorded between the different islands. Dana (12, p. 37), represents the islands as situated on a "Polynesian chain" and Gregory (17, p. 278) places them on a "South Pacific chain," but these ideas are based merely on the general alignment of the islands in relation to neighboring groups.

Existing knowledge is sufficient to indicate the probable nature and extent of earth movements in the southeast Pacific during Tertiary time. The evidence for the place and the amount of the movements is derived mainly from physiographical observations supplemented somewhat by lithological studies.

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The age of the movements has been determined by a fortunate paleontological discovery.

It is now known that several islands in these seas have more or less well defined plateaus at the summit of the volcanic mass which forms their nucleus. Such a platform on Mangaia Island at an altiude of 554 feet above sea level has already been described (25, p. 36).

A similar but far better preserved structure on Atiu Island has an altitude of only 270 feet and on the neighboring island of Mauke there seems to be a plateau only 100 feet above sea level. On Aitutaki Island the greater part of the volcanic ground appears to be a plateau which slopes from about 100 feet at the northwest to perhaps 30 feet at the southeast. However, in the north part of the island two small rocky peaks rise to the height of 300 and 450 feet respectively.

Chubb (6, p. 304) has described the remnants of a plateau on Rurutu Island, which lies nearly 400 miles east of Mangaia. In this island the plateau has an elevation of 800 feet above sea level and the highest point of the island (Manureva) is 1,400 feet. His description of Rimatara suggests a similar plateau on that island, at an altitude of only 315 feet. On the high mountainous islands of Rarotonga and Rapa, no plateaus are found though both of them have been closely examined. The other islands of the Austral group have not been described but it is known that Tubuai and Ravaivai have about the same altitude as Rurutu, and that Sands Island (Hull Island) is relatively low and consists of limestone. Of the other islands in the Cook group Mitiaro is a low limestone mass, Takutea merely a bank of coral sand, and Manuae a small atoll. For the Society Islands, 900 miles to the northeast, no plateaus cut in volcanic material have yet been described.

Thus, so far as known, plateaus of marine erosion exist in four islands of the Cook Islands and in one, perhaps two, of the Austral Islands. The height of the plateaus above present sea level is, however, different in all of the islands. It is highest in the southeast and decreases in altitude to the west and north. In Mangaia Island alone has the age of the plateau been determined and even that without exactitude. As previously shown (25, p. 42) the rim of raised limestone rock on Mangaia was deposited long subsequent to the formation of the plateau and a species of *Lepidocyclina* in the limestone proves that it is not younger than the middle Miocene. The formation of the plateau on Mangaia is, therefore, assigned to pre-Miocene times. No similar evidence has been discovered in the raised reefs of the other islands of the Cook group. Smith and Chubb (32) seem not to have made microscopical examinations of the limestones which they describe as continuous around Rurutu Island, attaining an altitude of 300 feet at Arei, and at even greater heights on the slopes of the central volcanic hill. This is clearly a reef lime-

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stone and is quite different from the small outcrop of detrital limestone that was found by Chubb on Rapa Island.

In the light of present knowledge it seems probable that the plateaus in the volcanic rock of all of these islands were formed at the same period of relative depression, but, of course, such a statement cannot be made with assurance. In any event they probably are not strictly contemporaneous. It would appear that the downward movement of the ocean floor that permitted the formation of these plateaus had its maximum amount (800 feet) at Rurutu, and diminished in a northwesterly direction to 554 feet at Mangaia and only 270 feet at Atiu. Eastward at Rapa there is no trace of this movement, nor westward at Rarotonga, and though a plateau is found at about 100 feet on Aitutaki, there is no trace of it in Tahiti or elsewhere in the Society Islands. It is, of course, possible though the physiographic evidence makes it highly improbable, that the Society Islands were not in existence when this downward flexing of the ocean floor took place.

The plateau of erosion at a relatively low level in Mangaia is pre-Miocene in age and in the lack of other evidence—a corresponding antiquity may be assumed for the plateaus on the other islands. There is no indication that folding or faulting was associated with this movement of the ocean floor. There seems to have been a slight tilting movement, which was perhaps greater at Aitutaki than elsewhere.

The next indication of movement of the sea floor is afforded by raised coral reefs found on many of the islands. Assuming that these structures began as fringing reefs that were actually united with the coast, the sea level was lower, or the ocean floor in this region had warped upward to a varying extent above its present position. Apparently, however, this difference was only slight, for everywhere the base of the inner edge of the raised coral is but little below the present sea level. At Rurutu it is actually above that level. At Mangaia this relatively high level was in the early Miocene, but this condition did not last long and was succeeded by a slow downward movement. The level fell 100 feet at Rapa, 300 feet at Rurutu, 216 feet at Mangaia, 70 feet at Atiu, about 70 feet at Mitiaro and Mauke, and only 15 feet at Rarotonga. There is no evidence of a fall at Manuae and Aitutaki seems not to have been affected. The Society Islands were outside of the area that was flexed. At Mangaia this movement ceased before the end of the Miocene period. Since this time there has been a gradual upward movement in all the islands until the present level has been attained. This at first was slow and nearly uniform though afterwards the uprise was less regular and at times rapid, as shown by the shore terraces at Mangaia. The general wide extent of the present fringing reefs is taken to indicate that the islands have remained with an unchanged elevation for a long period. The atoll of Manuae and the

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considerable barrier reef of Aitutaki indicate a different movement. In my opinion these structures indicate a depression in the northern part of Cook Islands. The atolls of Palmerston and Suvarov islands and the barrier reefs of the Society Islands show that the conditions of the ocean floor at Aitutaki extended also to these more northern islands.

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RAROTONGA

GENERAL FEATURES

The island of Rarotonga is elliptical in shape and almost exactly 20 miles in circuit. Its longer axis is nearly seven miles in length; its shorter axis, northeast to southwest, only five miles. The island lies in latitude 21° 12′ S. and longitude 158° 46′ W. (See map, fig. 2.)

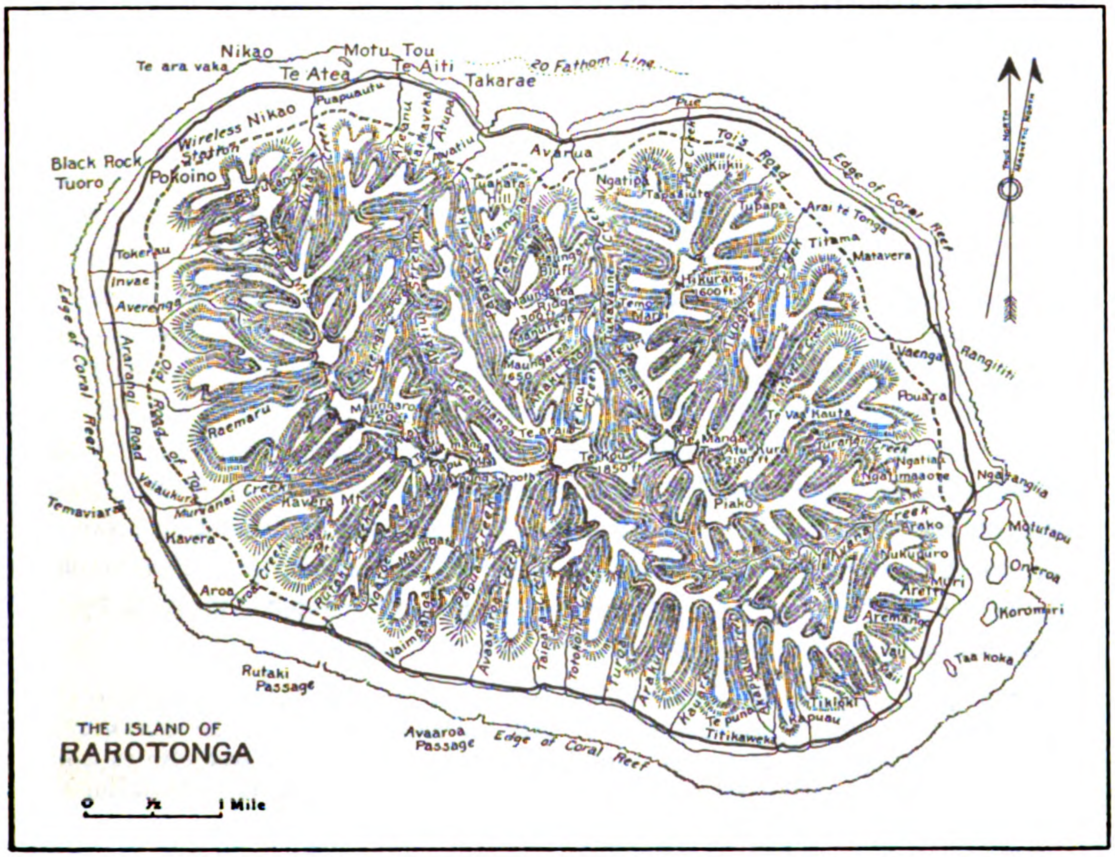

FIGURE 2.—Map of Rarotonga, outline based on a survey by H. M. Connal (1913). Physiographic and geologic features by Patrick Marshall (1925, 1926, 1927). Drawn by G. S. Druhot.

Like the other islands of the Cook group, Rarotonga is surrounded by a coral reef which fringes a low lying coast but the land soon rises rapidly into lofty hills with flanks that in many places are precipitous. The culminating point, Te Manga, has an elevation of 2,100 feet; the sharp and prominent peak of Hikurangi, close to the anchorage of Avarua, reaches a height of 1,600 feet; and several peaks with altitudes between 1,600 and 2,000 feet com-

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bine to give the island an appearance of ruggedness and grandeur that is not quite warranted by the actual height of the mountains. (See Pl. I, II, figs. 3-6.) The impression of grandeur is probably emphasized by the loneliness of the island, which is generally sighted only after several days have been passed at sea. Everywhere the island is covered with vegetation which, except in a few small areas, is most luxuriant and effectually hides the rock surface of even the most abrupt precipices. On the lowlands the coconut palm is most conspicuous but many other lordly trees are interspersed with it. Almost all of the hillsides are clothed with trees though a few places are covered only with ferns above which a few feathery toas (*Casuarina*) rise conspicuously. The bare hillsides coated with red clay which are conspicuous at Mangaia and Atiu, are absent from Rarotonga and the area of fern-clad hills is relatively far smaller than at Tahiti.

HISTORICAL SKETCH

John Williams, the well known missionary, often called "the martyr of Erromanga," was the European discoverer of Rarotonga so far as actual historical records are concerned. He first heard of the island from the natives of Raiatea, where he was stationed from 1817-1822. In 1822 he was told that on the island of Aitutaki were some natives of Rarotonga who had been placed there by a passing trading vessel. He at once visited Aitutaki, on which he had previously landed some Christian natives from Raiatea. He found the Rarotongans still there and from them he ascertained the position of their homeland. His first search for the island resulted in failure, but his second attempt after visiting Mangaia and Atiu was successful, when actually at the end of his resources. Williams was evidently much impressed by the appearance of Rarotonga. He writes (38, pp. 204-205):

> The high mountains, the rocky eminences, and the luxuriant valleys called forth our admiration. We were astonished to see the taro and kape, the ti and sugar cane growing luxuriantly nearly down to the edge of the sea. The whole island was also in a high state of cultivation, and I do not remember having seen anything more beautiful than the scene presented to me, when standing on the side of one of the hills looking towards the sea shore. In the first place there are rows of superb chestnut trees (*Inocarpus*), planted at equal distances, and stretching from the mountain's base to the sea, with a space between each row of half a mile wide. This space is divided into small taro beds which are dug four feet deep and can be irrigated at pleasure. These average about half an acre each. The embankments around each bed are thrown up with a slope leaving a flat surface upon the top of six or eight feet in width. The lowest parts are planted with taro and the sides of the embankment with kape or gigantic taro, while on the top are placed at regular intervals, small beautifully shaped breadfruit trees. The pea green leaves of the taro, the extraordinary size and deep colour of the kape lining the sloping embankment, together with the stately breadfruit trees on the top present a contrast which produces a most pleasing effect. . . . There is a good road round the island which the natives call "ara medua" or parent path, both sides of which are lined with bananas and mountain plantains; and these with the Barringtonias, chestnut and other trees of wide spreading foliage protect you from the rays of the tropical sun and afford

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even in midday the luxury of cool shady walks of several miles in length. The houses of the inhabitants are situated from ten to thirty yards or more from this pathway and some of them were exceedingly pretty. The path leading up to the house was invariably strewed with white and black pebbles; and on either side were planted the tufted-top ti tree or dracoena, which bears a chaste and beautiful blossom, interspersed alternately with the gigantic taro. Six or eight stone seats were ranged in front of the premises by the side of the "parent pathway." These were relics of antiquity, some of which were regarded with much veneration by the people; who, while they pointed to them, would say, "Here my father, grandfather, or the great chief so-and-so would sit." They were generally formed of two smooth stones, the one serving as a seat, the other sunk in the earth to form a back. Here in the cool of the evening, after the labors of the day, with a wreath of flowers on their brow, anointed with a sweet scented oil, and wearing a new tiputa or shining pakaku, sat the inmates of the house to chat with any loquacious passenger about the events of their own little world. . .

Their wars, I think, may also be considered sanguinary. In the one that raged just prior to our first visit, the king informed me that four score and ten were slain on the side of the conquerors and five score on that of the conquered. . . At Rarotonga there was not such an equality of rank as at Tahiti, but a man was great according to the number of his kaingas or farms, which contain from one to four or five acres each. These are let to tenants, who, like the vassals in the feudal system, obey the orders of their superior, assist him in the erection of his house, in building a canoe, making fishing nets, besides bringing him a certain portion of the products of his lands. This gives to the chiefs a degree of respectability.

Gill (15, p. 4), one of the first missionaries, gives some details of earlier visits of vessels to Rarotonga. He says that soon after the islanders had heard from the occupants of a drifted canoe about Captain Cook's visit to Tahiti, a vessel arrived off their coast. One of the Rarotongans who ventured on board the ship said that it was a floating island with breadfruit and other trees on board. This statement suggests that the vessel was the *Bounty,* which may have sighted the island in 1789, when the mutineers were bringing the captured vessel from Tonga to Tahiti. It is probable, however, that confusion has arisen with Aitutaki Island which was actually visited by the *Bounty* before the mutiny. Williams states that Rarotonga was probably visited by the *Bounty.* Meinicke (27, p. 139) says that the *Bounty* actually visited the island but quotes no authority for his statement. He also states that the island was sighted by the ship *Seringapatam* in 1814.

According to Gill the next visit (in 1820) was that of an unidentified merchant ship in charge of Captain Goodenough. A boat's crew was sent ashore at Ngatangiia but the natives there appearing hostile, the ship went to the northern side of the island, where it was received less boisterously. Finally the visitors removed to a little harbor to the east, where they stayed for three months. Before long their licentious and ruthless conduct with the natives led to slaughter of both natives and visitors, and Captain Goodenough found it advisable to leave the island, but he took with him some Rarotongan women whom he afterwards landed at Aitutaki. These were the natives whose presence in Aitutaki attracted the attention of Williams.

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The earlier native history of Rarotonga, briefly outlined by Williams (38, p. 192), has been given with full details by Smith (33, p. 109). According to Smith the island was first settled by Apopo, who hailed from Haapai about the year 875. At much the same time other voyagers came from the Marquesas but did not settle permanently.

The two important sources from which the island was populated were expeditions of Tangiia from Tahiti and of Karika from Samoa—both expeditions reaching Rarotonga in the year 1250. The descendants of these two pioneers are now the leading chiefs of the island. When Europeans first visited the island the most important chief was Makea of Avarua, the lineal descendant of Karika; but Pa, the descendant of Tangiia, was the most powerful military leader. Pa lived in the village of Ngatangiia, named after his ancestor. Another influential chief, though of less authority, was Tinomana, who lived at Arorangi on the west side of the island.

FLORA

Rarotonga has a far more varied flora than the other islands of the Cook group. This is a natural result of its greater altitude, wider diversity of soil, and greater variation of station. The high rainfall, which averages 78 inches annually and is generally distributed throughout the year, assures an abundance of moisture even in the lightest coral sands which everywhere fringe the coast. On the southern coasts, where the slopes are cooled by the frequent trade winds, the climate is hardly tropical even at the sea level, and here the coconut palm does not bear freely. On the mountain sides the climate is of the warm temperate zone and at an altitude of 2,000 feet moderately temperate conditions prevail. At Avarua the mean annual temperature is 75 degrees; the rainfall averages 78 inches annually, but within ten years has ranged from 116 to 61 inches. Any of the wet months, November to May, may have a fall of 15 inches.

A list of the Rarotongan plants was made by Cheeseman (5) in 1903. This work was the fruit of two months stay in the island during which all its mountainous portion as well as the lowland were traversed. He identified 235 species of plants which he considered to be indigenous, 80 species that he thought had been introduced by Europeans, and 19 which were supposed to have been brought by Polynesian voyagers from other islands. The plants introduced by Polynesians include, of course, the principal food plants, among them the breadfruit tree but not the coconut. Of the 235 indigenous Rarotongan plants 167 have been recorded in the Tahitian flora, 129 in the Tongan flora, and 103 as common to both groups. Only 18 species are considered by Cheeseman to be endemic. The likeness to the Tahitian flora is to be expected because of the similarity of soil, station, and climate, and from the comparative proximity of the two islands. It is particularly noticeable

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that the genera *Fitchia* and *Sclerotheca* are restricted to the Cook Islands and the Society Islands. No endemic genera have been discovered in Rarotonga.

In general features the distribution of the plants in Rarotonga is precisely that of Tahiti and other high islands of the Pacific. On the coastal strip *Ipomaea* and *Triumfetta* are prominent, while the first trees to be encountered are *Pandanus* and *Casuarina.* The widely distributed *Hibiscus* soon succeeds them and with it the coconut palm. At a short distance from the sea front are noble trees of *Barringtonia.* Their swelling trunks, as much as eight feet in diameter, give rise to spreading branches with many leaves, as much as a half square foot in expanse. An extensive area is shaded by a single tree. Here, too, grows the *tamanu* (*Calophyllum inophyllum*) used generally for canoe making, the banyan, orange trees, and many coffee bushes. There is a thick undergrowth of ferns and *Asplenium nidus* grows everywhere on the trees. In the damper ground and in the stream courses the "chestnut" (*Inocarpus edulis*) with its picturesque buttressed trunk is abundant. On the hills the candlenut (*Aleurites mollucana*) is everywhere conspicuous. Other genera well known in New Zealand are found here: *Metrosideros, Weinmannia, Myrsine, Elaeocarpus,* and *Coprosma.* In the deep and shaded valleys the native banana still finds a home. The curious genus *Fitchia,* which is represented by only one species, grows at sea level on the southern side of the island but not below 1,000 feet on the northern side. The great liana, *Entada scandens,* is everywhere and laces the foliage together, while in all the valleys *Hibiscus tiliaceus* forms almost impenetrable thickets, especially where it is associated with the gigantic fern *Angiopteris evecta,* which has fronds 15 feet in length. A characteristic plant of many of the ridges is an unidentified species of *Freycinetia,* its trailing and hanging branches greatly impeding progress.

Ferns are abundant. The species *Gleichenia dichotoma* covers those patches on the hills that are devoid of trees and as its interlacing wiry stipes reach a height of six feet it renders progress almost impossible. The three species of tree fern are far more abundant on the southern than on the northern side of the island. There are conspicuous species of *Pteris, Nephrodium,* and *Asplenium,* of which *A. nidus* is the most striking.

Of plants of recent introduction the papaw (*Carica papaya*) springs up in plentiful abundance in all cleared land, orange trees are numerous in all the valleys, and the guava (*Psidium*) readily spreads where the thickets are not too dense. The lantana has not spread in Rarotonga or elsewhere in Cook Islands to such an extent as to constitute the menace to agriculture that it has become in many tropical islands.

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NATURAL DIVISIONS

The Reef

The island of Rarotonga comprises four natural divisions, or geographic provinces here described as the reef, the beach and strand, the swamp, and the volcanic ground.

In Rarotonga, as in other reef-girt islands, a sharp distinction can be made between the raised outer edge of the reef or Lithothamnium ridge, which is above sea level at low water, and the reef flat which lies between this ridge and the beach and is covered by water at all states of the tide.

The reef is continuous round the whole circumference of the island, but it varies considerably in width. Along the northeast coast between Avarua and Ngatangiia its outer edge is close to the shore, especially near Ngatangiia village, but along the south and the southeast coasts it is nearly half a mile in width over a distance of five or six miles. The rise and fall of the tide is small. The reef flat is covered by a very shallow sheet of water even at high tide and at low water the Lithothamnium ridge is exposed but slightly between the surges. The seaward edge of the reef on the north side of the island is not so steep as in most places. Opposite Avarua a platform at a depth of less than 20 fathoms extends seaward for a third of a mile and along the coast for more than a mile—the entire area over which soundings have been made. The passes through the reef are few and narrow; the one most used is at Avarua, where lighters ply between the shore and vessels at anchor outside the reef. At Avatiu is a similar pass. Inside both these passes schooners are often moored but the shelter is poor. The pass at Ngatangiia is wider but the prevailing winds make it less accessible. The small passes at Arorangi and those on the south side of the island are seldom used because they are exposed to the prevailing ocean swell, and are dangerous because of the outward rush of water at the entrance. The floor of the entrance of the pass at Avarua at a depth of 5¾ fathoms is covered with large rounded boulders of coral rock, but careful inspection through a water glass failed to show any heads of growing coral on the bottom of this pass.

The edge of the reef is of the usual irregular form with projecting bosses, some above and some just below the surface of the water at low tide. Deep channels, narrow as crevasses, extend here and there far into the reef itself and on their sides coral heads of many kinds are growing freely. Corals grow in luxuriance on the flanks and round the base of the bosses of rock which extend seawards from the edge of the reef. On the edge of the reef itself where the thundering surf breaks eternally into foam there is little or no coral growth. The few heads that were seen do not develop a branching form; they lie flat on the surface of the reef. Here as at Mangaia, Atiu, and Aitutaki, the edge of the reef supports mainly a growth of various kinds of alga the most abun-

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dant of which are maroon colored members of the Floridiae, especially species of *Lithothamnium* and *Corallina* (or a related genus) which secrete a large amount of calcium carbonate in their cell walls. When the floor of the sea outside the reef is viewed through a water glass the edge of the reef is seen to slope down almost precipitously, but irregularly, to a depth of 4 to 5 fathoms. At this depth the surface of the rocks is generally covered with a growth of *Lithothamnium* and other calcareous algae. The principal species is maroon color, probably *Porolithon onkodes*. On the sides and in the crevices of these rocks corals of many species grow luxuriantly. From about the 5-fathom line, the sea floor slopes steeply outward and is covered with coral growth. At a distance of 50 yards from the reef are patches of sand from which many heads of coral rise. Here and there, however, the bottom is covered with large rounded boulders of coral rock among which no organic growth is present, owing presumably to the movement of the boulders during rough weather. These boulders are probably sinkers which are tied by native fishermen to their lines in such manner as to become detached when a fish is hooked. In the mouth of the pass which leads to the wharf at Avarua the boulders cover the whole of the floor at a depth of 5 fathoms. Proceeding outwards from the reef the sandy patches become more numerous and larger and the coral heads become smaller. This change continues until the limit of visibility is reached, a depth of 15 fathoms. No *Halimeda* was seen on any part of the sea floor.

Lithothamnium Ridge

The outer edge of the reef is a little higher than the reef flat interior to it, but on its exterior side it slopes outward between tide levels at an angle of 6 degrees. At Avarua this edge is less pronounced than usual but it may still be dubbed the "Lithothamnium ridge." It has the appearance of similar structure in Mangaia and other neighboring islands. It seems quite smooth in a general view but is extremely rough in detail. Its surface is very irregular and knobby and is everywhere perforated by deeply penetrating crevices which branch and reunite to form a structure which may be compared to a gigantic stony sponge. On the surface is a dense growth of various kinds of algae among which species of *Lithothamnium* have preeminence though mossy species of *Corallina* are common.

Corals, of course, are rare in this situation and when present lack the well known elegant branching forms which render them so attractive. They have a flattened corallum which adheres closely to the surface of the rock. In the various crevices corals grow in some profusion. The small importance of the Lithothamnium ridge on the north side of Rarotonga is probably related to the insignificant surf action there. The surface of the Lithothamnium ridge is about 18 inches above the level of the low water but the wash of the surf

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keeps it constantly wet at all stages of the tide. At high water the rush and force of the surf are great. The rough surface of this ridge does much to reduce the force of the surf without greatly opposing its violence at any one point. The ridge thus largely escapes damage.

A month before this shore was visited an unusually severe hurricane had been experienced, the force of the sea falling almost directly on the portion of the reef that was examined. It was found that although a number of new boulders (nigger heads) had been lifted onto the reef by the violence of the surf, none of these had been derived from any part of the Lithothamnium ridge which was intact throughout. At the part of the reef examined these nigger heads consist almost entirely of large masses of *Porites* which seem to grow beyond the steep outer edge. Likewise the nigger heads, which, judging from their appearance had lain on the reef for a long period, were almost exclusively formed of *Porites*. It thus appears that although the surf is sufficiently violent to break off and cast onto the reef large masses of coral that were growing outside it, the Lithothamnium ridge itself, which bears the brunt of the attack of the surf, is strong enough to resist its force without damage. Under normal conditions the sea floor outside the edge of the reef is quite free from disturbance by the surf, but during the occasional severe hurricanes, when waves of huge size break on the reef, this outside floor becomes subject to the most violent action. It is here that the giant waves recoil and fall headlong. The coral growths are formed during long periods of quiet conditions and develop a structure and anchorage which are unable to resist the strenuous wave action during hurricanes. They may be broken off in large masses and be thrown onto the surface of the reef.

Reef Flat

The surface of the reef on the south side of Rarotonga has relatively few nigger heads on the reef flat though here the prevailing ocean swell breaks with greatest violence. The explanation is perhaps to be found in these considerations: the surf is here so constantly heavy that any coral that is thrown onto the reef is at once washed farther, and onto the beach; the exceptional hurricanes which afflict Rarotonga only once in twenty years bring the heavy and destructive sea from the north, the surf on the south side of the island being little more violent than usual.

The reef flat at Rarotonga is relatively narrow. On the west and north it has an average width of 200 yards; on the northeast 50 yards; and on the south and southeast 500 yards. The water that covers it is generally shallow especially on the north and west sides of the island, but is far deeper on the south side.

Corals grow freely in all the deeper portions of the water that covers the reef flat, but throughout its extent erosion appears to balance growth. Near

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Avarua it is possible to cross the reef flat dry foot at low water. Even on the south side of the island the depth of the water on the reef flat is not great enough to produce the impression of a lagoon between the coral reef and the shore.

Beach and Strand

For almost the complete circuit of Rarotonga the coast has a dazzling white sandy beach formed of fragments of the various organisms that grow on the reef and in the water outside of it. On the south side a considerable variety of molluscan shells can be obtained; elsewhere they are rare. Tests of Foraminifera make up a very small portion of the sand and in only a few places is there any typical beach rock (coquina). For a short distance near Matavera, the beach is formed of cobbles of coral rock. Here the reef is narrow and in ordinary weather the heavy seas at high water break full onto the surface of the beach. It is noticeable that here the beach rises in two terraces of cobbles, both of them far above the limit reached by the waves in ordinary weather. The terraces are only five feet wide and are composed of rather heavier cobbles than those on the lower part of the beach. The lower of these terraces, about six feet above the limit of ordinary storm waves, was reached by the hurricane of March, 1926, said to have been the most severe in twenty years. During this storm, which ruined the banana crop for the year, the waves swept over the beach at Avarua and Arorangi and destroyed some buildings.

The upper of these two small terraces is much the older. Its surface and also the slope between the two terraces is crossed by a trail formed by the natives in going down to the reef. Along this trail in the upper terrace the surface of the cobbles is worn smooth by the bare feet of the natives though on the lower terrace no such wearing can be seen. It is possible that this upper terrace was formed by the waves during the violent hurricane of December 22, 1831 recorded by Williams (38, p.390).

The beach of Rarotonga appears to maintain its form and size with a good deal of constancy but during hurricanes portions may be swept away, and the material removed may extend the coast where it is sheltered from the hurricane seas. The places where such changes take place naturally depend upon the direction of the striking force of each particular hurricane. During the storm of March, 1926 the beach between Arorangi and Avatiu suffered most. The beach rises with a uniform slope to a height of 10 to 12 feet and its summit is strewn with rough loose blocks of coral on the west and north sides of the island. The ground maintains this height of 12 feet above high water mark for a distance averaging 100 yards when it sinks down again almost to the sea level. This 12-foot strand extends nearly around the island. The only interruption is between Ngatangiia and Titikaweka, where the reef

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flat has its greatest width and four small islands stand on it. These islands stand a quarter mile from the beach, near the edge of the reef and form a line which continues the curve of the coast lying to the north of Ngatangiia. They seem to be remnants of a former coast line and it is possible that a hurricane of unusual power broke through an older coast line to the low ground beyond it and left its separated remnants as islands. This idea is supported by the fact that at Te Muri, opposite the islands, there is now no flattened ridge nor swamp behind it; the volcanic rock extends to the beach. The only similar occurrence is at Black Rock (Tuoru) where the tongue of a phonolite lava flow actually reaches the sea. Here, however, the lava flow projects out so far as to invade the region of the coral beach on the rounded curve that is naturally developed under the influence of marine action. This flat-topped strand, as displayed in low cliffs near Ngatangiia, has the structure of a coral reef and is not a mere accumulation of reef debris deposited in this position by heavy storms. The coral rocks contain an abundance of coral heads in the position of growth. It is, therefore, reasonable to consider this flat strand as an old reef which was separated from the shore by a shallow lagoon which has become the swampy area that separates the coral rock from the rising ground of volcanic origin.

Swamp

The swampy ground is variable in extent, but in most places not more than 200 to 300 yards wide. Most of it is drained by channels that pass through the raised coral strand which separates the swamp from the reef flat. The streams that drain the highlands do not take the overflow from the swamp; they build fans over which they pass at a level higher than the floor of the swamps. In times of heavy rainfall the swollen streams may give part of their water to the swamps. The Tupapa, however, has a subterranean outlet.

In this swampy ground the greater part of the taro, the staple food of the natives, is grown. The old road of Toi (Ara Medua), which was the highway before the advent of Europeans, marks the inner limit of the swampy ground. At the Black Rock (Tuoru), however, the old road lies somewhat to the landward of the edge of the volcanic ground and crosses some of it. At Te Muri, where there is no swampy ground, the old road is not to be seen.

Volcanic Ground

From the inner side of the swampy ground the volcanic slope rises quickly and in many places abruptly. Most of the spur ends which radiate from the high country have truncated terminations due in all probability to marine erosion before the growth of the coral reef began. The hills rise with great steepness from the valley floors and the dividing ridges between adja-

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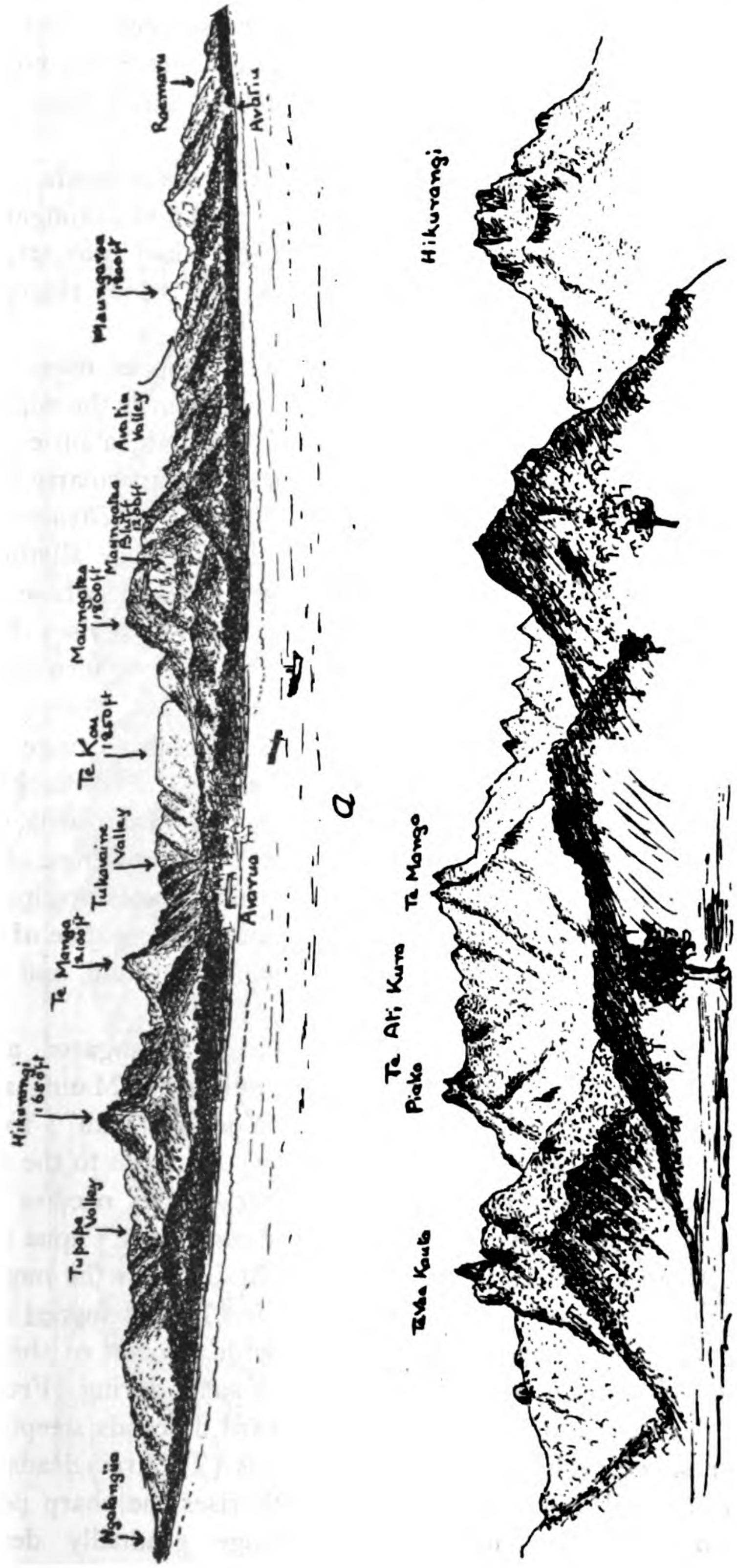

FIGURE 3.—Sketches showing topographic features of Rarotonga: *a*, view from the anchorage at Avarua; *b*, view of highest peaks from coast line near Matavera.

cent valleys are extremely sharp and in consequence the surface of the island is rugged and craggy. In spite of this the peaks and ridges reach no great heights; the summits have altitudes between 1,600 and 2,100 feet. (See map, fig. 2.)

Except for the peaks of Hikurangi and Maungatea the main heights of the island lie along a well defined ridge running west to east from Maungaroa to Piako, a distance of three miles. Branching from this main rampart three ridges with high points extend in a northerly direction and a long ridge without prominent peaks runs southeast.

The prominent hill called Raemaru is a relatively flat-topped mass with a slight westerly slope and bordered by a steep scarp which marks the edge of a flow of sodalite-phonolite lava. The conical hill of Tongoiti, a little to the southeast of Raemaru, is composed of basalt. Raemaru is particularly noticeable because its surface is covered with a carpet of fern (*Gleichenia dichotoma*) with a few toa (*Casuarina*) trees rising through it, while all the surrounding hills are covered with the mixed forest which gives the whole island such an attractive appearance. A smaller flat-topped hill, which rises directly behind the village of Arorangi, also is covered with a growth of fern and toa, and is capped with sodalite-phonolite lava.

On the western side of the island all the spurs rise to a sharp ridge trending 10 degrees west of north and terminating on the coast near Black Rock (Tuoru), but on the south end of this ridge the peak of Maungaroa marks the turning point to the east-west main mountain line of Rarotonga. On its northern side this westerly ridge falls steeply and in many places precipitously to Avatiu Valley. The peak of Maungaroa, which attains an altitude of 1,750 feet, occupies the commanding position in the center of the island, and forms an excellent viewpoint (fig. 6, *a*).

The main island axis, when followed eastward from Maungaroa, at first falls sharply, but soon becomes more even. A half mile from Maungaroa an extremely sharp aiguille known as Maunga Tapu ("Youngs Tooth") forms a conspicuous object from the sea off Avatiu (fig. 6, *c*). A little to the southwest of Maunga Tapu are several lesser but rather similar needles called Te Maunga Rua. They are clearly visible from the coast near Papua on the south side of the island. A mile and a half from Maungaroa the mountain axis rises sharply to the summit of Te Kou (1,850 feet) a flat-topped mountain capped with trachytoid phonolite and covered with a forest of the usual Pacific island type. In the center of its flat top is a small spring. From Te Kou a prominent ridge extending north-northwestward descends steeply then rises to a small, unnamed peak, north of which a pass (Te Arai) leads from Tukavaine Valley to Avatiu Valley. Farther north rises the sharp peak of Maungatea (1,750 feet), beyond which the ridge gradually descends (fig. 4, *a*); its main axis ends in the steep Maungatea Bluff (fig. 6, *b*), but a

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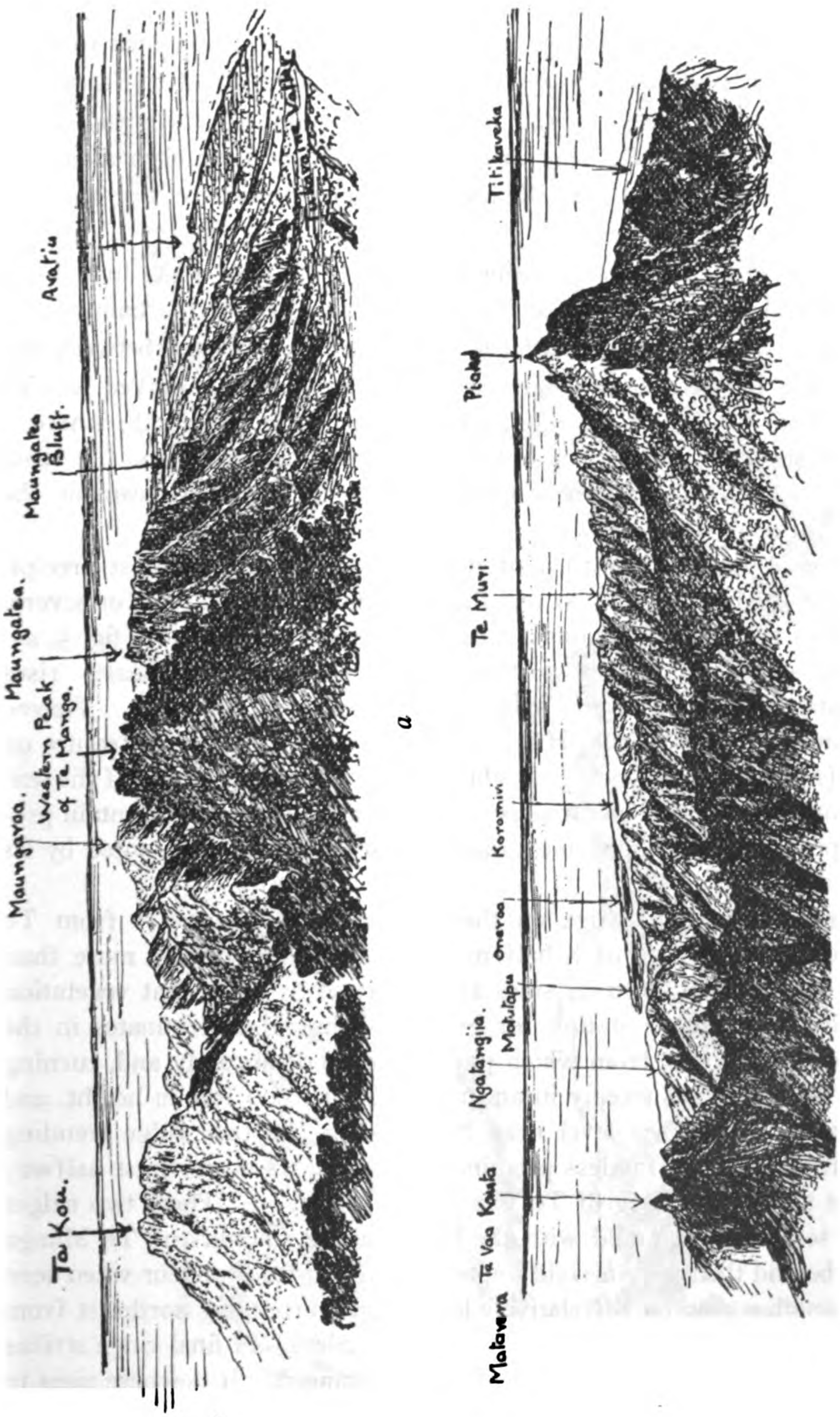

FIGURE 4.—Sketches showing topographic features of Rarotonga as seen from the summit of Te Manga: *a*, view looking west; *b*, view looking east.

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small branch descends more gradually and terminates in the sharp pointed Tuakata Hill almost at the village of Avarua. Most of Maungatea ridge is formed of sodalite-phonolite, but the highest summit consists of coarse basalt. The descent of the ridge to the Tukavaine Valley is extremely steep (fig. 5, *b*). On the northern side of Maungatea a basalt which contains no olivine forms a lava flow beneath the phonolite, but the distance over which it extends could not be ascertained.

From Te Kou the main ridge of the island (fig. 3, *a*) continues in an easterly direction at a high altitude to Te Manga (2,100 feet), the culminating point of Rarotonga. This part of the ridge forms the divide between the Tukavaine and the Avana drainage basins. From its double-peaked top Te Manga descends steeply on all sides, but particularly on the south, where it falls almost sheer to the valley of Avana River, which, rising on Te Kou, enters the sea at Ngatangiia, four miles distant—the longest stream on the island (fig. 4, *a*).

From Te Manga northward a prominent ridge descends almost precipitously, but at an altitude of 1,300 feet the slope flattens and except for several small aiguilles the ridge maintains a uniform height for two miles (fig. 5, *a*). It then curves slightly from north-northwest to north-northeast, rises abruptly, and terminates in the spear-shaped peak of Hikurangi. Viewed from the anchorage at Avarua, Hikurangi is the most conspicuous feature on the island (fig. 3, *a*). It rises to a height of 1,650 feet within a mile of the seacoast (a slope of 1:3) and as the upper 300 feet are abrupt the mountain presents an appearance of height and grandeur, not altogether warranted by its actual elevation.

The most outstanding ridge on the island extends southeast from Te Manga and for a distance of a half mile maintains a height of more than 1,900 feet (fig. 3, *b*). Both its sides are so extremely steep that vegetation has difficulty in finding a station for growth. The ridge terminates in the sharp pinnacle of Piako, from which point it descends abruptly and, turning sharply to the east, rises steeply in an unnamed hill 1,600 feet in height, and finally slopes down to sea level near Ngatangiia. Another ridge trending northeast from Piako is far less prominent, but it bears on its crest halfway to the coast the striking crag of Te Vaa Kauta (fig. 4, *b*). These two ridges with their serrated crests and with the commanding summits of Te Manga and Piako behind them give a vivid impression of rugged grandeur when seen from Ngatangiia. A ridge of relatively low elevation trending northeast from Te Manga separates the Tupapa and Matavera valleys. A final ridge strikes southeast from Te Kou and terminates near Ngatangiia. It nowhere rises to any great height.

The outstanding physiographic features of Rarotonga are clearly not

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FIGURE 5.—Sketches of Tukavaine Valley: *a*, view of east side from Upper Tukavaine; *b*, view of head and west side.

original; they are not directly due to the volcanic activity to which the island owes its origin. Apart from the evidence offered by the lithology of the rocks (pp. 28-31) a mere inspection of the relief map of the island (fig. 2) shows that the rugged profile and prominent peaks are due to subaerial erosion. In very few places, such as the sloping summit of Raemaru and the

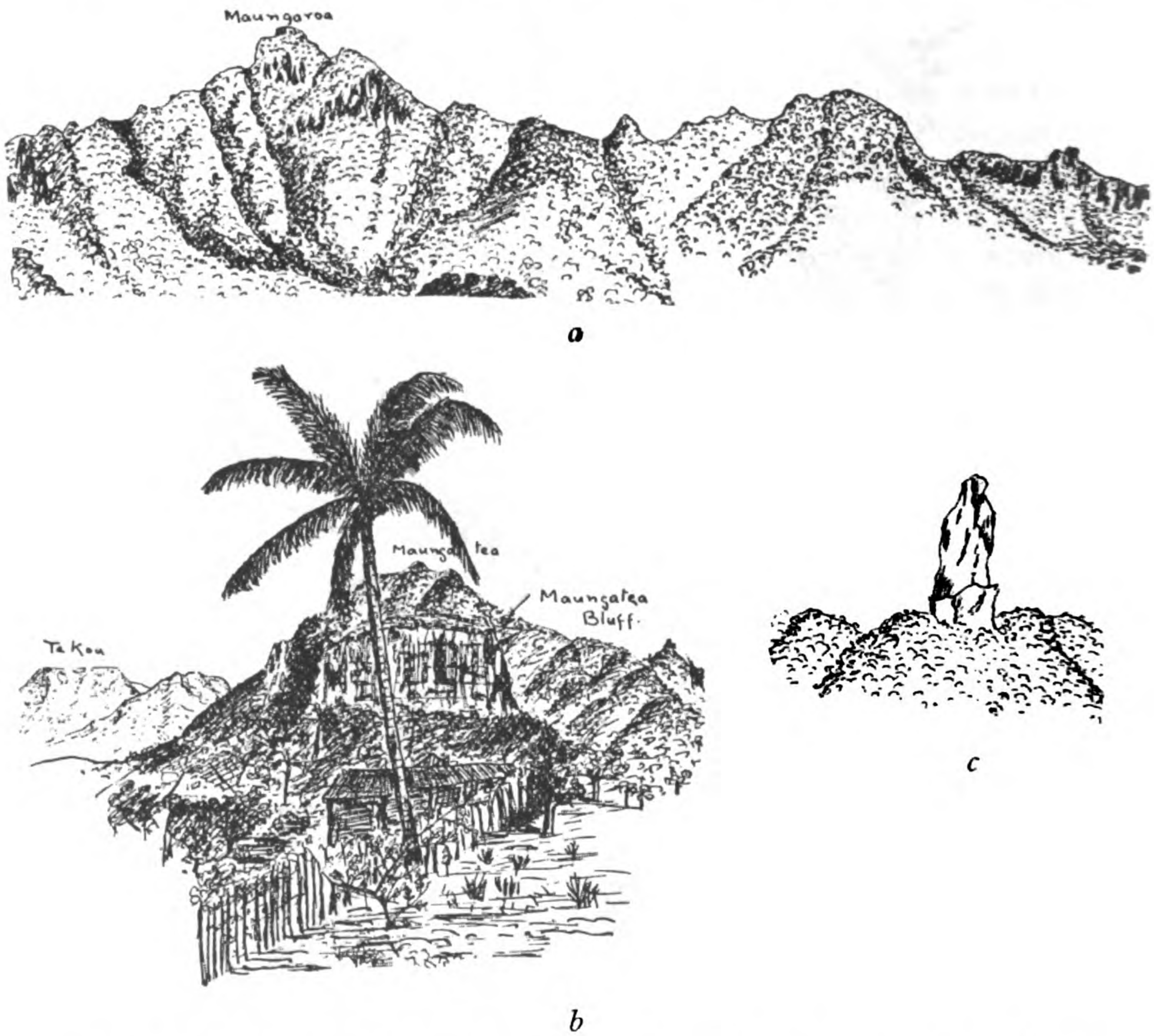

FIGURE 6.—Sketches showing topographic features of Rarotonga: *a*, view of west side of Avatiu Valley; *b*, Maungatea looking south from Avarua; *c*, Youngs Tooth as seen from Upper Avatiu.

relatively flat-top of Te Kou, do the original surfaces of the massive lava flows remain. Most of the hill summits are remnants of beds of scoria. Te Manga and Tapu are survivals of erosion which removed large masses of material. Hikurangi and Te Vaa Kauta owe their prominence to the fact that they are the outcrop of dykes.

The ridges have the "razor back" form, common to tropical islands of

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volcanic origin. The cause of this exaggerated physiographic form is not clearly understood. It generally has been ascribed to the effect of violent tropical rainfall on land areas which had an initial slope of great steepness. Observations in Rarotonga led to the opinion that this peculiar form of ridge is due in part at least to the protection afforded by the tropical growth of vegetation. Trees growing near the summit of one of the ridges have roots that extend over it and become fixed in the rock on the further side. The bracing of these roots combined with the lacing of climbing plants give the crest of the ridge a resistance and solidity not possessed by the flanks. There is thus developed a tendency for the flanks to flake away in severe weather while the crest of the ridge remains relatively secure. It seems, however, that other causes must operate perhaps in equal degree, as ridges in regions of light rainfall are said to have a "razor edge" form as exaggerated as those on other tropical islands. It is noticeable that on Mangaia and other islands of the Cook group the "razor back" type of ridge has not been developed. However, the altitude of these islands is small and the denudation far less extensive than in Rarotonga.

It was noticeable in Rarotonga after the hurricane of March, 1926, that considerable areas of the steep flanks of the mountains had been completely stripped of vegetation and that the trees had carried with them the skin of rocky material in which the roots had anchored. So far as observed, none of the ridge crests were stripped.

IGNEOUS ROCKS

Classification

The structure of the volcanic ground could not be studied in detail though a large amount of information was obtained. The precipitous nature of the hills, the absence of trails over the greater part of the island, the thick covering of interlaced tropical vegetation, the frequent heavy rains all combine to hinder geological work and in some places effectually prevent it. The rock masses comprise four main types:

1. Basaltic tuffs and scoria
2. Basaltic lavas and dikes.
3. Phonolitic tuffs.
4. Phonolite lavas.

In general it may be said that basaltic tuffs and scoria constitute the more prominent peaks of the island, and phonolitic tuffs the most striking physical features. Phonolite lavas have a somewhat wider extent than the other rocks. Basaltic lavas and dikes are relatively small in amount.

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Basaltic Tuffs and Scoria

The basaltic tuffs of Rarotonga are composed of large fragments of coarse-grained, black, basaltic material embedded in finer grained tufaceous matter. The boulders of basalt contain large idiomorphic crystals of augite of typical form and also large anhedrons of olivine. These tuffs are thought to constitute the greater part of the slopes extending from near shore to the tops of the highest hills though in places they are covered with phonolitic material. Along the shore they are represented by red clay soil, the product of deep weathering and oxidation.

In its unoxidized state, the tuff is well exposed in the middle part of Tukavaine Valley, where a huge landslide in the distant past descended from the ridge which connects Hikurangi and Te Manga. The presence of this rock at high levels in the center of the island and its very wide extent beneath other volcanic rocks along the coastal slopes of the volcanic hills justify the opinion that the tuff is the oldest rock in the island. Its thickness must have amounted at least to the height of the island (2,000 feet). Because of its weathered surface and the dense cover of vegetation, outcrops of the rock are rare. The largest observed are behind Avarua and on the outer slopes of the hills farther east. Typical material may be seen in the grounds of the Church Mission at Avarua.

The structure of the tuff clearly indicates that the earliest eruptions of which there is any record in Rarotonga were violent explosions. The finer matrix in which the boulders of coarse basalt are embedded is red and the oxidation to which this color is due appears to be original and indicates that these early eruptions were subaerial.

The finer material of this scoria contains a number of sharp angled augite crystals as much as 20 mm. in length. They show the crystal faces usual in basaltic augite, but many of them show the orthodome (p. -101). Several crystals are twinned in the usual manner with the orthopinacoid, the twinning and composition plane. In this scoria there are a few fragments of phonolite —a proof that eruptions of alkaline rock had preceded the formation of these scorias, which are the lowest rocks now exposed. It suggests the condition at Otago Harbor where in the long series of eruptions alkaline lavas, principally phonolites, preceded and succeeded outflows of basalt (24, pp. 382-408).

Basaltic Lavas and Dikes

No coarse-grained basaltic lavas were found in place. In many streams boulders of this rock are plentiful, but observations made it seem probable that they were all derived from the scoria beds or, to a far less extent, from dikes. Lava flows of fine grained basalts do not seem to be common. There

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are, however, two flows beneath the phonolite of Maungatea; the upper a medium grained lava, the other finer grained with no phenocrysts of augite or olivine.

Dikes are rather more common. A coarse-grained dike seen at the point where the Avatiu enters its mountain gorge is 10 feet wide and strikes 60°. Another of similar texture at the entrance of the gorge of the Tauae, near Avarua, is 8 feet wide and strikes 50°. Still another dike, 9 to 12 inches wide on the cliff face of Maungatea Bluff, penetrates the breccia as well as a mass of coarse basalt 5 feet wide striking 60°. That numerous dikes traverse the rocks of the island cannot be doubted but the thick covering of vegetation conceals them so effectually that few were distinguished. The summit of Hikurangi seems to owe its resistance to a dike and it is possible Te Vaa Kauta is the outcrop of another dike.

Phonolitic Tuffs

The exposure of phonolitic tuffs are in steep cliffs at Maungatea Bluff, Youngs Tooth, and on the west side of the Avatiu Valley. The rocks are light gray in color and contain fragments of many kinds of lava as much as a foot in diameter. The pebbles collected include basalts of various types.

This breccia is a solid rock mass almost free from joints of all kinds but it is roughly stratified. On the west side of Avatiu Valley unequal weathering of the different strata has produced an irregular cliff with projecting ledges and sheltered recesses in which the "bosun" bird makes its nests. Like some of the other more abrupt features of the island the bluff at the northern end of the Maungatea Ridge, which has a cliff face some 300 feet in height, owes its steepness to the physical characters of the breccia. Maunga Tapu (Youngs Tooth), the conspicuous aiguille at the head of the Avatiu Valley (fig. 6, *c*) and the other aiguilles, which show up so conspicuously from Papua when looking towards the north, are also formed of this material.

At Maungatea Bluff the phonolitic breccia seems to rest on highly weathered basaltic breccia, and on the east side of the bluff near its summit, there are some basaltic lava flows. These facts lead to the opinion that at this place the breccia fills an explosion cavity and is, in fact, an agglomerate. It may be that these basaltic lavas are of a later period and flowed round a denuded remnant of the breccia. The presence of basaltic dikes on the eastern side of the bluff gives support to this suggestion and makes it necessary to assume two periods of basaltic eruption, one preceding, the other succeeding the phonolitic eruptions. That this is not an improbable assumption is shown by the fact that in Dunedin eruptions of basic material occurred both before and after those of alkaline lavas more than once in the history of a single volcanic area.

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The eruption of these alkaline rocks may have been due to submarine activity; the materials of the breccia are quite unoxidised, and the stratification which is distinct in Maungatea Bluff points to sorting by water. On the other hand, no fossil remains were found in this breccia.

Phonolite Lavas

A great emission of alkaline lavas succeeded the scattering of the tuffaceous phonolitic matter. The area covered by these lavas is considerable though, judging by the absence of pebbles of this material in the stream

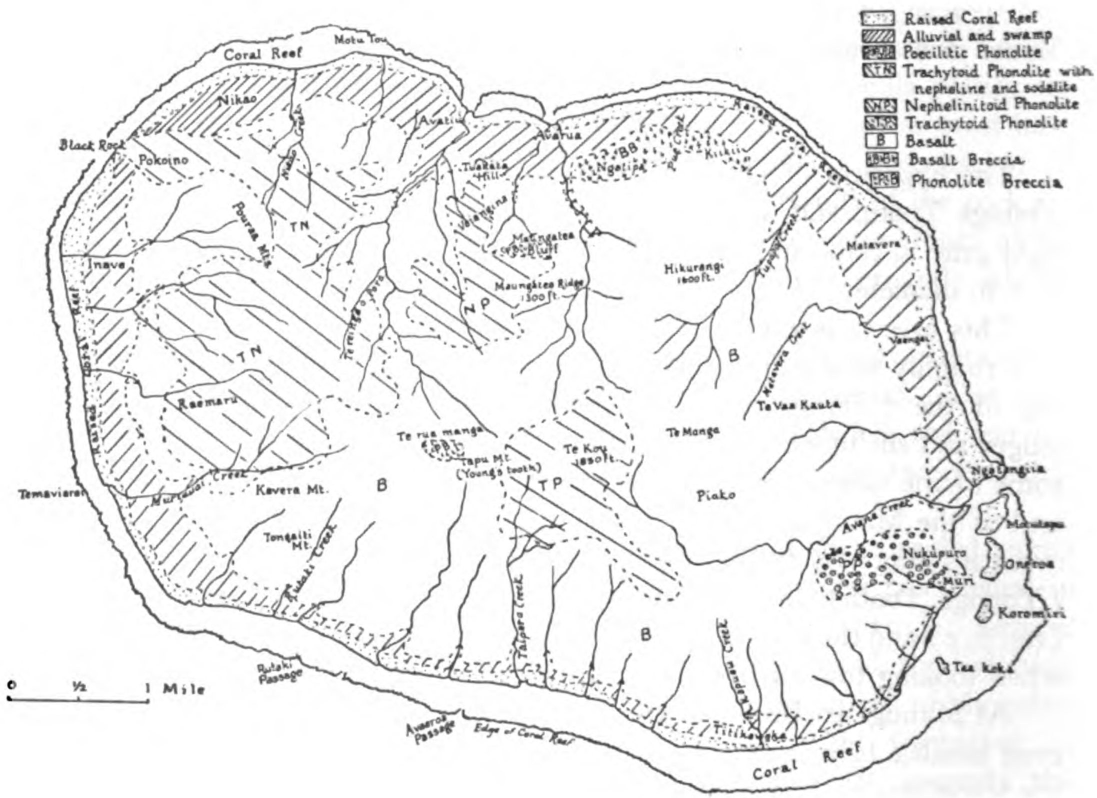

Figure 7.—Geological map of Rarotonga.

courses, none of it is to be found in Tupapa or Matavera valleys and very little in Avana Valley. The points from which the alkaline lavas were erupted could not be located, though it is important to record that lavas of this type reach sea level at Te Muri and Black Point and also at Tuakata, near Avarua. The summit of Raemaru is formed of a lava flow with a pronounced tilt southwesterly. Much of the summit of Maungatea Ridge and seemingly all

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of the flat top of Maungatea Bluff consist of alkaline material though of a slightly different composition. On the other hand no outcrop of alkaline lava was seen on the floors of any of the valleys which at many places cut through the volcanic material almost to sea level.

The conclusion is obvious that the alkaline lavas were emitted from elevated positions within the island and flowed outwards from what are even now the high lands. Te Kou may well have been one of the points of eruption but the existence of many others is suggested by the distribution of the rocks and their composition (fig. 7).

The ridge of Maungatea appears at first sight to be a continuous lava flow that extended outwards from Te Kou. These two elevations, however, are composed of different materials and actually the alkaline rock is by no means continuous along the summit of the ridge; in several places on it basaltic rock occurs. Even the small outcrop at Tuakata Hill is probably an independent mass derived from a local eruption or intrusion.

On the ridge extending north from Maungaroa is a dike of phonolite, 11 feet wide, trending east-west. It is the only one seen on the island. The mantling of the coast of the island with a covering of coral rock prevents the structure of the volcanic rocks from being displayed by marine erosion.

PETROGRAPHIC DESCRIPTIONS

Phonolites

Several types of phonolites can be distinguished in Rarotonga, but the centers from which they were erupted cannot be located, owing to the large amount of denudation that has taken place.

Microscopically these phonolites are dense rocks with a dark greenish tint. Some fresh surfaces have the greasy luster often associated with abundant nepheline.

A trachytoid type, which comes from the top and southern slopes of Te Kou, consists mainly of microlites of sanidine or soda-orthoclase but these are mixed plentifully with somewhat irregular prisms of aegerine (Pl.III, *F*). Iron ore, apparently magnetite, is not uncommon in well formed, but minute, crystals. There are no phenocrysts in the rock. Between the feldspar and aegerine microlites is a good deal of a perfectly transparent colorless mineral with a very low refractive index and an extremely low birefringence. This mineral could not be identified with certainty. The choice lay between such a zeolite as analcite or chabazite and sodalite, determined by Smith and Chubb (32, p. 324) as the interstitial mineral of the sodalite-phonolite of Rapa Island. The same or at least a similar material has evidently a wide occurrence in rocks of this nature. It is clearly the constituent of the base of phonolites that was called a glass by Rosenbusch (28, p.970) and by Zirkel (40, p.442).

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Both of these authors remark that the substance (glass) dissolves readily in acid. Zirkel quotes several analyses of this soluble portion of the rock as well as the residue after treatment with acid. Most such analyses have little value for this portion of the rock may contain such minerals as nepheline and sodalite as well as the isotropic glass of the base, all of which are soluble in acid.

Microscopic study of the interstitial material in the phonolite from Te Kou showed that nepheline and sodalite are absent. It was found that 27.12 per cent of the rock was dissolved in hydrolic hydrochloric acid in the dilute state and just raised to the boiling point. When acid of different strengths was used and the temperature not raised to the boiling point the same amount of material was dissolved. The dissolved matter consisted of the following ingredients:

	Percentage	Molecular Proportions	
SiO_2	34.10	5.68	12
Al_2O_3	29.53	2.90	6
Fe_2O_3	1.20		
TiO_2	.96		
CaO	4.44*	.68	
K_2O	3.63	.38	
Na_2O	16.00	0.55+2.63	
P_2O_5	.66		
H_2O	7.49		
Cl	1.10	.55	

*Part of the CaO is calculated to make apatite with P_2O_5 and sphene with TiO_2.

These analytical results lead to the conclusion that the dissolved substance is a definite mineral with the composition 7 (Na_2O, K_2O, CaO) $6Al_2O_3$. $12S_1O_2$+NaCl closely related to sodalite which has the composition 3 Na_2O 3 Al_2O_3 6 SiO_2+NaCl. The question, however, arises as to whether the water that is present in the rock is a constituent of the mineral but as it is not affected by a high temperature water is not likely to be present. Subsequent tests showed that dilute silver nitrate stains the mineral. The chlorine is obviously very loosely held. Zirkel (40, p. 147) comments on the relatively low silication of the dissolved portion of phonolitic rocks compared with the insoluble portion and the surprising amount of lime that passes into solution and notes that it is not accompanied by a corresponding amount of magnesia. In the analyses given by him the rock from Messid Gharian is the only one in which chlorine is estimated in the soluble portion and in this rock recognizable sodalite is present. The fact that the chlorine of the Rarotongan rock seems to be concentrated in the soluble portion appears to support the view that the substance is a definite mineral, not merely a glass. The name ameletite is proposed for the mineral (αμελης, overlooked). A more definite occurrence of this mineral recently found at Dunedin, New Zealand, is described in the "Mineralogical Magazine" (Vol. 22, No. 127, 1929).

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It was found that the sodalite-phonolite on the top of the Maungatea Bluff (Pl. III, C) contains as much as 62 per cent of material soluble in dilute hydrochloric acid. This is a higher percentage of soluble matter than that in any of the rocks quoted by Zirkel. This soluble portion has the following composition:

SiO_2	41.30
Al_2O_3	29.67
CaO	3.87
K_2O	2.87
Na_2O	11.74
H_2O	8.71
Cl	2.10
	100.26

Zirkel (40) notes that the composition of the soluble portion of these rocks approaches that of nepheline. This is true for the rock from Maungatea Bluff though the presence of water and lime introduces a complicating feature. Because this rock contains sodalite and nepheline as well as some zeolitic matter attempts to determine the composition of its interstitial matter from this analysis would not be satisfactory.

The phonolite from Black Rock (Tuoru), which forms a large lava flow on the northerly extension of Maungaroa, is also trachytoid but its feldspar microlites are smaller and no magnetite is present. It contains many minute nepheline crystals as well as some of larger size and also crystals of sodalite but in less abundance than in other rocks of this type in the island. Isotropic matter between the feldspar microlites is common. The rock which forms the prominent flat summit of Raemaru covers the greater part of its western slopes and extends northward for a considerable distance along the hill slopes towards Tuoru, is yet more alkaline in composition (Pl.III, *A*). Though microlites of feldspar are still abundant nepheline is more common: but the minute crystals of this mineral tend to become localized in well defined areas especially in association with patches of aegerine. Sodalite too is more abundant and the interstitial matter here called ameletite, supposed to be a mineral allied to sodalite, has a general distribution through the rock. A few crystals of sphene are present.

A highly alkaline phonolite occurs at Te Muri, extending from sea level to the top of the ridge between that place and Avana Valley. It contains no microlites of feldspar but the mineral is present in the form of small plates, with highly irregular boundaries, which include, in poecillitic manner, crystals of nepheline, aegerine, and sodalite. The nepheline also includes microlites of aegerine which are also molded around many small crystals of sodalite. A few crystals of sphene are present. As in most rocks of this group there is no iron ore. The order of crystallization is clearly: sodalite, aegerine, nepheline, feldspar.

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The nature of this rock was not fully understood when previously described by me (22, p.99). It is rather a more coarsely crystalline type than the other phonolites, and the high percentage of water shown in the analysis indicates that a considerable amount of zeolite mineral is present. Some spaces in the rock are filled with these minerals. This is the type of Lacroix' rock species, murite (19, p.32).

A somewhat similar type of phonolite comes from a lava flow at the top of the Maungatea Bluff and the ridge south of it. Here the nepheline crystals are large and contain abundant zonally arranged microlites of aegerine. The sodalite is more distinct and contains the same dusty brown material in the center as at Te Muri. There is very little feldspar but the zeolitic mineral seems to be more plentiful.

The rock that forms a precipice near the southern end of the Maungatea ridge is perhaps the most interesting of the Rarotongan phonolites. In hand specimens the rock is a dark green color and has a number of vacuoles partly or wholly filled with white zeolites. (See Pl. III, *B*).

In microscopic slices it is found to be extremely dense and to consist mainly of a network of small aegerine needles, in the meshes of which are a few small crystals of nepheline and sodalite. Here and there roundish spaces filled with isotropic matter can be distinguished. These contain large numbers of concentrically arranged needles of aegerine. The whole combination closely resembles that described by me (21, p.405) in a somewhat similar rock from Puketeraki near Dunedin, New Zealand, which was identified as leucite. The meshes of the aegerine net in the Maungatea rock are generally filled with a colorless mineral that has feebly birefringent properties which seem almost certain to be a zeolite, perhaps chabazite. The vacuoles which are filled with zeolites proved to be of great interest. In many places needles of aegerine augite project into the cavities and some are suspended in the zeolitic matter and have no apparent connection with the walls of the cavity (Pl. IV, *A*). This striking feature affords convincing proof that the zeolites that fill the space are primary constituents of the rock. Several different species of zeolite are found in each of the cavities (Pl. IV, *B*). Most of the cavities are lined with an isotropic mineral of low refractive index, probably analcite. Inside this border in many cavities are two distinct types of radiating crystal groups: one having strikingly long fibers; the other, which is far more common, consisting of shorter, wider crystals with pyramidal terminations and a relatively high refractive index. Another mineral has small crystals so arranged in a feathery form that it is difficult to distinguish the individuals. The more central part of the larger spaces is filled with a zeolite having a low refractive index, and arranged as relatively large interlocking plates. It is thought that the zeolite in coarsely radiating groups is natrolite, that the finely radiating species may be scolecite, and that the species in the center are

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perhaps chabazite. When a section is treated with silver nitrate and subsequently with potassium chromate the species in the mass of the rock and that in the central portion of the vacuoles stain in a conspicuous manner.

This rock clearly belongs to the sodalite phonolite series of Rarotonga. The conclusion reached from a study of the walls of the cavities that the zeolite minerals which fill them are primary is supported by the consideration of the possible origin of the minerals. The nepheline and sodalite of the rock are quite fresh in the section, and therefore, cannot be the source of the zeolite. The feldspar also is unweathered.

Another type of sodalite phonolite, represented by boulders from the bed of the Tukavaine stream shows the extreme form of nephelinitoid development. In it nepheline is notably the most prominent and well developed mineral (Pl. III, *D, E*). The crystals have the usual hexagonal or rectangular sections and are crowded with microlites of aegerine arranged in concentric zones. The largest ones measure 0.5 mm. in length. There is little feldspar but an abundance of aegerine. A few crystals of a greenish brown hornblende with a moderate resorption border and a few crystals of sphene of an extremely pale brown tint are present. Between the nepheline and aegerine crystals there is a good deal of a platey feebly birefringent zeolite. The exact place from which this specimen was derived is not known but it is almost certain that it came from some part of the Maungatea Ridge.

A still more peculiar form of rock is represented only by a boulder found in the bed of the Tukavaine. The plentiful feldspar in this rock is apparently soda orthoclase in somewhat irregular crystals 3 mm. long and 0.5 mm. wide. The aegerine too is in rather coarser grains than usual. No nepheline or sodalite is to be seen but there is a great abundance of well crystallized and perfectly transparent zeolites. Many of them are arranged round the feldspar crystals and none display an arrangement or outline that suggests that they have been formed from any preexisting mineral such as nepheline or sodalite.

However, the rock contains no crystals of these minerals. Quite unaltered aegerine projects into the mineral aggregations in a manner that suggests the same period of formation as the zeolites. This rock is light grey in color and shows on a fractured surface conspicuous cleavage planes of feldspar.

Examination of these types of alkaline volcanic rocks from Rarotonga produces a strong impression that the several species of zeolite which occur in them are primary. It is generally recognized that analcite occurs in many volcanic rocks. In New South Wales natrolite is regarded as a primary constituent of some rocks.

Table 1 shows how widely the phonolitic rocks are distributed in the south central Pacific Ocean. The composition of the basic rocks here presented or of the much fuller series given by Lacroix studied in conjunction with that of the phonolites so often associated with them shows that the lavas in these

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TABLE 1. COMPARATIVE ANALYSES OF PHONOLITES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	47.52	54.60	49.20	50.80	52.40	52.00	54.15	53.80	56.12	57.00	59.00	57.60	56.40	58.91	60.50	60.46	62.44	56.78
Al_2O_3	15.18	17.48	22.15	22.96	20.19	21.09	16.09	18.72	21.32	18.56	17.09	20.78	15.84	17.20	18.20	19.17	18.87	18.29
Fe_2O_3	5.98	5.72	4.21	3.84	4.01	3.21	7.35	4.99	2.59	4.58	5.30	4.00	6.48	1.99	1.34	1.81	1.87	5.01
Fe O	3.17	1.02	2.07	1.62	1.70	1.63	4.90	3.59	3.29	2.76	3.25	3.50	3.54	4.86	1.89	1.95	0.87	1.23
MgO	1.61	1.44	0.15	0.21	0.24	0.14	1.61	0.86	0.56	0.41	0.21	0.35	0.21	0.44	1.18	0.16	0.62	1.31
CaO	7.42	3.10	2.95	2.75	3.20	4.15	3.86	2.80	2.30	1.05	1.46	1.98	1.52	3.33	1.75	1.44	1.35	2.42
Na_2O	8.11	9.32	7.80	8.45	8.33	8.23	5.94	8.82	5.79	6.43	7.47	6.05	5.80	7.28	7.25	7.46	7.29	5.35
K_2O	3.84	5.61	3.58	4.12	4.08	4.28	4.41	5.20	4.81	6.34	5.39	4.67	5.78	4.50	4.45	4.68	5.66	4.24
NO_2	1.92	0.80	1.20	1.14	1.08	1.20	0.41	0.30	......	......	0.41	0.52	......	0.43	0.92	0.12	0.62	0.59
P_2O_5	0.63	......	0.45	0.70	0.14	0.31	0.42	......	......	......	0.42	......	0.13	0.09	......	0.06	0.09	0.11
H_2O	3.62	1.56	5.20	1.46	2.00	5.86	1.40	1.90	1.54	2.96	2.32	2.60	3.96	0.72	......	1.32	0.32	2.34
H_2O	1.25	......	......	1.14	......	......	......	......	......	......	......	......	......	0.20	......	0.56	0.17	2.33
MnO	......	......	......	......	......	......	......	......	......	......	......	......	......	0.18	......	0.25	0.21	......
Cl_2	......	......	......	......	......	0.61	0.40	0.14	0.34	0.45	......	......	......	0.16	......	0.26	......	0.08

1. Murite from Te Muri Point, Rarotonga: Lacroix (19, p. 32).
2. Nephelinitoid phonolite from Maungatea, Rarotonga: Marshall (26, p. 98).
3. Nephelinitoid phonolite from Maungatea Bluff, Rarotonga: Marshall (this paper).
4. Trachytoid phonolite from Maungaroa, Rarotonga: Marshall (this paper).
5. Trachytoid phonolite from Te Kou mountain, Rarotonga: Marshall (this paper).
6. "Zeolitic phonolite," from a boulder in Tukavaine Valley, Rarotonga: Marshall (this paper).
7. Trachytoid phonolite from Signal Hill, Dunedin, New Zealand: Cotton (9, p. 120).
8. Nephelinitoid phonolite from Signal Hill, Dunedin, New Zealand: Cotton (9, p. 121).
9. Trachytoid phonolite from Mount Cargill, Dunedin, New Zealand: Bartrum (3, p. 173).
10. Trachytoid phonolite from Logan's Point, Dunedin, New Zealand: Cotton (9, p. 118).
11. Trachytoid phonolite from North Head, Dunedin, New Zealand: Marshall (21, p. 393).
12. Trachytoid phonolite (lava 25) from North Head, Dunedin, New Zealand: Marshall (21, p. 393).
13. Sodalite-phonolite from Mopanui, Dunedin, New Zealand: Marshall (21, p. 406).
14. Sodalite trachytoid phonolite from Rapa Island: Smith and Chubb (32, p. 325).
15. Phonolite from Vairao, Tahiti: Lacroix (18, p. 112).
16. Trachyte phonolitique from Huaheine Island: Lacroix (19, p. 30).
17. Rock from Tapioi, Raiatea Island: Lacroix (18, p. 29).
18. Rock from Papetoai, Moorea Island: Lacroix (18, p. 26).

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islands are derived from magmatic material in which silica was not present in sufficient quantity to form feldspar with all the alkaline bases: in other words, the magma is not saturated with silica.

It seems clear that in this magma, magnesia, lime, and iron united with silica in the proportions required for the stable minerals olivine, augite, and (or) hornblende and a few accessories. The amount of silica required in the formation of these minerals leaves an insufficient quantity to form feldspar with the large amount of alkaline oxides present; though there is usually enough silica to permit the formation of some feldspar. This sub-saturation with silica permits the formation of nepheline and sodalite molecules and these minerals crystallize before the feldspar. The obscure mineral substance ameletite is related to sodalite but has a still lower percentage of silica and crystallizes after the feldspar. The small excess of lime also enters into this compound.

The composition of the Maungatea nepheline sodalite phonolite and of the boulder from Tukavaine Valley indicate that in some rocks at least the excess of alkali and alumina is combined with silica and water in the formation of zeolite molecules and that these minerals may be original components of the igneous rock. Analcite has long been recognized as a constituent of monchiquites and teschenites and there is no reason to deny to other zeolites what is permitted to analcite.

In the natrolite-tinguaite lately described from Dunedin (26, p.533) the large spherulites of natrolite have not been derived from the alteration of either the feldspar or the nepheline of the rock for they remain quite unchanged.

No attempt is made here to account for the physical or chemical separation of that portion of the magma which solidifies into ankaramites and oceanites from that portion which solidifies into phonolites though it is thought that the difference in specific gravity (3.20 and 2.62) is significant. The separation of the two series is undoubtedly sharp though the basanitoids of Lacroix can be regarded as a connecting series. In Rarotonga the basalt flow that lies below the phonolite at Maungatea is regarded in this light. No specimen was found which showed an inclusion of phonolite in basalt or of basalt in phonolite.

Nesoite

The lava found below the phonolite at Maungatea is a close-grained rock slightly vesicular in texture and greenish grey in color. It is composed mainly of small elongated crystals of feldspar and augite quite aphyric in their arrangement. The feldspar has a maximum extinction angle of 15 degrees and appears to be an acid andesine. The small prisms of augite are of a very pale color but show a distinct violet tinge. There are a few small flakes of

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a brown pleochroic biotite and some yellowish green serpentinous material which is clearly a decomposition product though it does not seem to represent olivine. Magnetite is abundant. A large part of the rock is composed of a clear colorless mineral with a low refractive index and extremely low birefringence, without cleavage or other distinguishing structures. The mineral is certainly original in the rock and it is thought to be a zeolite probably chabazite. When treated for five minutes with cold dilute hydrochloric acid 12.6 per cent of the rock dissolved. Of this 4.4 per cent was found to be alumina and 1.4 per cent, lime. Assuming that the 5.4 per cent of water found in the analysis constituted part of the dissolved matter, all the residue, 1.4 per cent, was probably soda. The alumina would represent a percentage of 22 per cent of chabazite in the rock, the lime and soda 24.2 per cent, and the water 26.3 per cent. It thus appears that about 20 per cent of the rock consists of chabazite or of some mineral similar to it. The mineral is attacked by silver nitrate and on treatment with potassium chromate a deposit of silver chromate is formed. This large amount of original zeolite is such a remarkable feature that it has been considered justifiable to give the rock a distinctive name and nesoite is proposed for it.

Ankaramite

A rock that is placed in the group of highly basic volcanics called ankaramites by Lacroix occurs rather widely in Rarotonga, though no mass of it was found in place. Large fragments of it are contained in a mass of breccia in Tukavaine Valley, derived from the ridge between Hikurangi and Te Manga. It is widely distributed in the basin of the Tupapa River and breccias which contain fragments are exposed on the top of Te Manga, Maungaroa, and at many places on the higher ridges of the island.

The rock is coarse-grained with idiomorphs of augite, pale brown in section, and as much as 15 cm. long. Olivine grains may be 5 cm. long (Pl. IV, *C*). The finer portion consists mainly of anhedral augite, a few feldspar microlites that show a low angle of extinction, and grains of magnetite, some as much as .5 cm. in diameter. Some zeolitic matter occupies the residual spaces.

Basalts

Basalts are widely distributed in Rarotonga Island, but most outcrops of these rocks are concealed. Most of the specimens collected came from boulders in stream courses. Exceptions are the dike at Tokerau and the dikes on the eastern flank of Hikurangi. The basalt at Tokerau, at the entrance to the small Tauae Valley near Avarua, could probably be classed with the ankaramites of Lacroix. In this rock phenocrysts of augite and olivine are about equal in number. The larger crystals of augite are idiomorphic

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and pale brown in color with a yellowish tint in the center and a violet tint near the margin. The crystals may be 10 mm. in length while the olivine grains do not exceed 5 mm. The ground mass is composed mainly of anhedral augite with labradorite microlites and much titaniferous iron ore, most of it in long slender crystals, but some granular. Residual patches between the feldspar microlites are mostly isotropic but many of them contain a highly refractive mineral which is also strongly birefringent. This is certainly calcite and the conditions of its occurrence convince an observer that it is original.

A boulder found in the Tukavaine stream proved to be a basalt containing large idiomorphic augites, many euhedral crystals of olivine, and a few slender and small phenocrysts of labradorite. The ground mass is mainly composed of diopside but magnetite is abundant and there is some interstitial isotropic matter.

One of the native stone axes is composed of basaltic material. In it the olivine has been completely changed to a serpentinous substance; the feldspar consists of slender, small crystals of labradorite; the augite is anhedral and of a pale greenish tint. Much fine magnetite is also present. The origin of this rock is not known.

Another basalt pebble from the Tukavaine stream is composed of the same material as the dyke that traverses the breccia at Maungatea. This rock, however, has no phenocrysts of augite nor of olivine and contains more microlites of feldspar. A few small flakes of brown mica are present.

A basaltic rock forming a dyke on the eastern flank of Hikurangi has no phenocrysts and contains no olivine. It consists of a dense intergrowth of feldspar microlites and anhedral augite with magnetite. Though the rock is quite fresh, small grains of calcite are distinct in some interstitial spaces. Since the feldspar is andesine this rock may probably be classed with the andesine andesite from Rapa, described by Smith and Chubb (32, p. 332).

A basalt pebble from the breccia of "Young's Tooth," is a slightly vesicular rock in which olivine has been replaced by serpentine and the steam pores filled with secondary materials. It contains only a few feldspar microlites, but these are quite fresh. A pale brown augite forms the greater part of the rock; though a good deal of magnetite is present. Throughout the rock, many of the augite crystals are arranged in the form of rosettes with six to twenty slender crystals. Another rock from the breccia forming Youngs Tooth is a typical basalt with abundant magnetite. In the specimen examined the olivine grains are changed to serpentine around the margins and along the fissures. Otherwise augite and labradorite feldspar appear in about equal quantities as well formed microlites.

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Picrite Porphyry

In Maungatea Bluff, a nearly vertical dike,—one foot thick and trending south-southeast, is composed of picrite porphyry. The rock is dense, black in color, and has a specific gravity of 2.99. It contains idiomorphic crystals of pale brown augite, and many rounded grains of olivine somewhat altered to iron oxide and serpentine. These are set in a dense fine network of diopside prisms in the meshes of which are small grains of magnetite. There are some microlites of andesine feldspar and a very small amount of brown glass.

In both mineralogical and chemical composition this rock closely resembles the peridotite of Papenoo Valley, Tahiti, described by Lacroix as "pyroxenolite" or "diopsidite à olivine" because he considered it too deficient in olivine to justify its classification as peridotite.

Another rock of an identical nature forms numerous small rounded fragments in a breccia at the north end of Aitutaki Island. These consist of crystals of diopside with olivine grains partly changed into iron oxide, and some serpentinous substance.

The basic rocks of the ankaramite-oceanite suite of Lacroix have a wide distribution in the islands that rise from the depths of the Pacific basin and as is implied from the necessity of assigning them to a special class they are practically unknown outside this area except at Madagascar which may be said to occupy a position in the Indian Ocean somewhat analogous to that of Juan Fernandez in the Pacific, and in Christmas Island which rises from the depths of the north Indian Ocean. Here the limburgite recorded by Smith (31, p. 61) clearly has the general nature of the basanitoids of Lacroix; a group well represented in Tahiti and other islands.

Lacroix (19) shows that representatives of this ultra basic series occur in Tahiti, Raiatea, Rapa, Mangareva (Gambier), Tutuila, Hawaii, and Juan Fernandez. They also appear at Mangaia and Rarotonga, though in Mangaia they occupy a small area, and in type they approach the basanitoids rather closely. In New Zealand, however, no exact equivalents have been found. The coarse dolerites and basalts of Dunedin which at first sight resemble them have actually large crystals of feldspar, and their analyses show a greater percentage of silica. Some of the basalts of Hyde 20 miles distant have a smaller amount of feldspar, but they have not yet been fully studied.

Lacroix (18, p.44) regards the rocks of the ankaramite-oceanite series as the extreme product of differentiation, and remarks that one type of oceanite from Putua, Mangareva Island, "constitute reéllement la forme d' epanchement du'une péridotite." It would seem, however, that the complete absence of feldspar in the periditite of Papenoo Valley, Tahiti, and in the dike equivalent at Maungatea, Rarotonga, indicates an even more extreme effect of

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differentiation: but whatever its origin, the distribution of this very exceptional basic rock type justifies an inquiry into its geological significance. The analyses presented in Table 2 clearly show that the combination of extreme basic and alkaline—or nepheline-bearing rocks is an ordinary condition in the oceanic islands of the south central Pacific region, notably in Tahiti, Raiatea, Huahine, Rarotonga, Aitutaki, Rapa, and Upolu.

TABLE 2. ANALYSES OF ROCKS FROM PACIFIC ISLANDS

	1	2	3	4	5	6	7	8	9
SiO_2	46.20	44.94	46.59	46.90	43.10	42.14	43.29	44.88	42.19
Al_2O_3	16.50	17.30	15.19	16.13	8.94	8.36	9.10	10.50	9.03
Fe_2O_3	3.58	4.15	3.30	4.26	4.56	7.05	6.88	1.55	3.08
FeO	6.41	5.33	8.97	7.85	9.94	6.35	7.25	9.22	9.27
MgO	3.17	3.93	4.69	4.37	15.92	16.03	16.21	15.19	13.89
CaO	8.40	8.34	8.06	7.43	10.10	12.62	10.11	10.61	11.95
Na_2O	4.52	5.14	3.67	5.34	1.67	1.42	1.44	1.37	1.77
K_2O	2.11	3.03	1.42	1.84	1.14	0.93	0.88	1.15	0.47
TiO_2	2.62	3.20	4.01	3.56	2.40	3.12	2.84	3.03	2.72
P_2O_5	0.42	0.69	0.18	1.25	0.27	0.31	0.32	0.65	0.71
H_2O	5.40	2.74	1.68	0.56	1.60	0.93	1.48	1.88	1.03
		0.60	1.11	0.57	......	0.88	0.54	0.64	1.02
MnO	......	......	0.18	0.15	......	0.10	0.14	0.16	0.19
Total	99.30	100.24	100.11	100.21	99.66	100.24	100.59	100.03	100.10

1. Basalt below nephelinitoid phonolite (basanitoid?) at Maungatea, Rarotonga Island: Marshall (this paper).
2. Basanitoid from Punaruu, Tahiti: Lacroix (18, p. 2).
3. Olivine trachybasalt from Hiri Bay, Rapa Island: Smith and Chubb (32, p. 332).
4. Olivine bearing nepheline tephrite from Rurutu Island: Smith and Chubb (32, p. 336).
5. Rock from Tupapa Valley, Rarotonga Island: Marshall (this paper).
6. Ankaramite basanitique from Tahiti: Lacroix (18, p. 29).
7. Ankaramite porphyrique from the west coast of Raiatea Island: Lacroix (18, p. 29).
8. Ultra basic basalt from Vairu, Rapa Island: Smith and Chubb (32, p. 326); basalte passant á ankaramite: Lacroix (18, p. 37).
9. Labradorite basalt from Fangaloa Bay, Samoa: Bartrum (2, p. 253).

The list of islands showing basic and alkaline rock in combination may well be extended when the relatively large islands of Tahaa, Borabora, and Mangareva are better known. Even present knowledge suggests a common nature or identity in the magma that underlies all this large portion of the Pacific Basin.

This similarity is strongly supported by the presence of the ultra basic differentiates in the three islands of Tahiti, Aitutaki, and Rarotonga. The wide distribution of the highly basic ankaramite-oceanite suite and the threefold appearance of the diopside olivine rock justify the conclusion that this original magma was of an extremely basic nature and of high specific gravity.

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GEOLOGICAL HISTORY

The geological development of the island of Rarotonga can be described in more simple terms than that of Mangaia and Atiu, two of the other islands of the Cook group, for there is far less evidence of movements of the strand line. As in the other high islands of the southern Pacific a volcanic eruption was the prelude to the first appearance of land. Rarotonga may be considered as the summit of a large volcano most of which is submarine. So far as known the base of this volcanic mountain stands 12,000 feet below the sea level and its total height is no less than 14,000 feet. It is of course, possible that the Rarotongan and Mangaian mountains are confluent at their bases and further that Cook Islands as a whole constitutes a single group of volcanic mountains.

The dissection of the volcanic mass of Rarotonga must have produced a large amount of detritus but this great quantity of waste has not built up a definite platform on any part of the coast, at least with reference to the present sea level. The larger stream valleys such as Tukavaine and Avatiu, have flat floors 200 yards wide where they emerge from the mountainous part of the island. Their gravel covered floors indicate the possibility that the valleys were at one time deeper and in consequence of a slight submergence were filled up with detritus to the new sea level. Such a movement could well account for the anchorage bank which extends off the coast opposite this part of the north side of the island for a distance of three quarters of a mile, and a quarter to a third of a mile beyond the present reef. The few soundings taken outside the reef at the north end of the island are sufficient to show this well defined platform at a depth of less than 20 fathoms. When viewed through a water glass this bank seems to be covered with small coral boulders, but in most places the covering is sand in which heads of coral are common.

It would seem that in Rarotonga, as in Mangaia, the growth of coral did not begin until the erosion had reached almost its present stage, possibly when the period of depression had commenced. It is reasonable to suppose that such a movement would decrease the amount of detritus transported to the coast and thus not check the growth of coral, so the inner edge of the coral bank or the outer edge of the taro swamp would indicate the position of the sea margin at that time. As the downward movement of the land proceeded, the upward growth of the coral would enable it to keep at the surface of the water. When a still-stand condition supervened, the reef would begin to extend outward—its growth depending upon the length of time the still-stand lasted. At Rarotonga, it continued while the reef grew outward some 200 yards. An elevation of a maximum amount of 15 feet then took place and since that time the present fringing reef has grown outward a further dis-

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tance of 50 to 440 yards in different parts of the island, apparently without any variation of the sea level.

Throughout the great lapse of time during which the growth of the coral reef has been in progress stream erosion has progressed very slowly. The amount of gravel deposited on the reef by the streams is quite small. The floor of the passage through the reef at Avarua opposite the Tukavaine stream is covered with large boulders which when viewed through a water glass appear to be a foot in diameter, but as the water is 4 1/3 fathoms deep, it is hard to make an estimate of the actual size. The boulders appear to consist of coral rock but they may be volcanic boulders encrusted with calcareous organisms. It is thought, however, that the movement to which these boulders are subject whenever the surf runs high might keep them clean from such growth. The amount of gravel transported by the stream has been insufficient to fill this passage.

The opinion that there has been little or no elevation since the growth of the present fringing reef began is based on the absence of stacks of limestone on the present reef, such as would be expected if elevation had taken place. On the other hand, the shallowness of the reef flat proves that no downward movement has occurred since the outward growth was initiated.

Since volcanic activity ceased in Rarotonga, the island has not been deeply submerged. On the flanks of the hills no erosion platforms, no beach deposits, and no coral growth were seen. The valley system also shows no traces of adjustment to any level markedly different from that of the present day, though the slight filling in the lower courses of the Tukavaine and the Avatiu is a consequence of a small movement of depression.

AGE

During the prolonged period of still-stand, since the coral growth began, the erosion due to atmospheric action has been profound; the floors of many valleys are as much as 1500 feet below the crests of the ridges on either side of them. Whether the conditions of erosion in Rarotonga were the same as in Mangaia and Atiu, neighboring islands of much less altitude, cannot be definitely stated, but there is no particular reason to suppose otherwise. In both of these islands the rate of erosion has been extremely slow for during the time that the volcanic rocks have been submitted to its action, a coral reef has formed and grown out for a distance of two-thirds of a mile from the foot of the volcanic rocks. At Mangaia the inner edge of this mass of coral rock is certainly not younger than the middle Miocene period, and since that time the island has been continuously subject to the attack of subaerial agents of erosion. Yet the original flat summit of this small island has not been completely dissected and on many of the spurs there are conspicuous flat surfaces. For Atiu, the age of the inner part of the Makatea is unfortunately

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not so well known, but the island is not likely to be much younger than Mangaia (25). Small as is the dissection in Mangaia and Atiu, it seems to have been mainly, if not entirely, effected before the Miocene period. Little erosion has taken place since then for the depression between the volcanic hill and the Makatea has not been filled. In Rarotonga the coral growth has not been so extensive as in the other two islands, but the total amount of erosion is enormously greater and it would seem if the rate of erosion in Mangaia and Atiu is taken as a criterion Rarotonga must date back to the Cretaceous period.

Apart from this paleontological method, the physiographic features are of value in determining the age of the islands. By calculating the present rate of erosion, and assuming that rate to have been constant for a long geological period, the time required for the agents of denudation to produce the actual amount of dissection represented in the present land forms can be estimated by applying this method in combination with a knowledge of the rate of accumulation of volcanic material. Wentworth (36, pp.52-57; 37, p.118) estimated the age of the island of Lanai, Hawaii, as 200,000 years; of Oahu, as not less than 2,500,000 years.

When, however, consideration is given to the extremely slow rate of erosion in Mangaia these estimates for the age of the Hawaiian islands seem altogether too low. On the other hand, isolated volcanic masses in New Zealand, of Miocene or later age, such as those in the Dunedin region and the Coromandel Peninsula have suffered as much denudation as Rarotonga. On the whole, it may be stated that because Rarotonga has been denuded to much the same degree as Oahu and to a much greater extent than Mangaia, it is reasonable to state that it cannot be younger than 2,500,000 years and it may be of early Tertiary age.

ALKALINE ROCKS IN THE PACIFIC OCEAN

It is now well known that a variety of alkaline igneous rocks occurs in the islands scattered over the basin of the Pacific Ocean, and they have perhaps their most varied development in the Society Islands, as has been shown by Lacroix (18, p. 91) and by me (23, p. 196).

More recently alkaline rocks have been recorded from the islands of Rapa and Rurutu lying about 500 miles east of Rarotonga. These rocks are distributed over districts where, as Washington (34, p.341) has pointed out, there is no shore line that indicates a structure of the Atlantic type. The islands show no evidence of rapid elevation or depression that could be associated with a faulted structure of the ocean floor.

Judging from the few soundings available, there is every reason to think that in the neighborhood of these islands the ocean is 2000 to 2500 fathoms deep. At Mangaia it has been shown that the relative level of island and

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ocean has varied no more than 600 feet since the early Tertiary. The island of Atiu conveys similar information. It would appear then that present knowledge of the ocean floor is in harmony with the evidence for the permanence of the islands and of the small amount of movement that they have demonstrably undergone.

On the other hand, in all of the islands in which they are known to occur, the alkaline rocks are associated with basic rocks with low silica content and of high specific gravity and are of much smaller volume than the highly basic types with which they are associated. The alkaline rocks, too, have a relatively low silica content. It would seem that these phonolites represent differentiation products of the silica unsaturated, heavy, magma by which it is thought the basin of the Pacific Ocean is underlaid. Though the phonolites have a relatively low specific gravity their volume in relation to that of the basic rocks is so small that the mean specific gravity of all of the rocks of any one of the islands would probably be high.

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ATIU ISLAND

HISTORICAL SKETCH

Atiu Island, a coral rimmed volcanic mass with a circumference of 12 1/2 miles and a summit height of about 250 feet was discovered by Captain Cook on March 31, 1777. The account (8) states that Lieutenant Gore with two boats landed on the reef, taking with him Omai, a native of Huaheine. The Atiuans welcomed the visitors and carried them from the edge of the reef to the beach, a narrow stretch of sand, from which a slender defile led through jagged limestone rocks to a strand thickly covered with vegetation. The white men were then conducted to a marae (*morai*) half a mile farther on, where three chiefs were seated some distance apart, and between them lines of men armed with clubs. Lieutenant Gore found that the natives were gradually separating his men with the object, he thought, of detaining them. There were even suspicions that ovens were being prepared with sinister intentions. It seems, however, that the islanders merely wished to detain the white men ashore and entertain them in a lavish manner and that the ovens were being heated to cook pigs. Gill (15, pp. 186-187) states after questioning the natives that they would certainly have detained the visitors but for the exaggerated tales of Omai who told them that the ship's guns could easily destroy the island and kill every person living on it. He also states that during their stay on the island, the visitors were the guests of the chief Tiaputa.

Lieutenant Gore and his men were able to leave the island and embark again without molestation, but Gore complains of the crowding by the natives and the fact that his men were virtually prevented from making any observations on the geographic features of the island, or the condition of the people.

The actual point of landing was at Orovaru on the northwest side of the island (fig. 11). My native guide Ngapaku showed me the place: a small sandy beach with rugged limestone on either side crowned with toa trees (*Casuarina equisetifolia*). From the head of this small nook a defile leads with a gradually rising floor to the top of the level strand which runs round all the western part of the island. From the strand a path leads to the marae (*morai*) of Orongo where Tepaku told me the reception of Gore by the chiefs took place. This old marae is still in a good state of preservation. The walls are 2 feet 3 inches high, built in part of large stalactites taken from a cave, in part of limestone blocks, and in part of boulders of volcanic rock which must have been diligently sought and carried a considerable distance. The larger platform measures 12 by 15 feet, and the smaller, 8 feet distant, 4 by 5 feet. All the adjoining ground is covered with small limestone pebbles carried from the strand. Ngapaku said that the chiefs had their allotted positions near the marae and that the people were assembled between them and the adjoining swamp.

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Lieutenant Gore seems to have been less successful than Captain Cook in dealing with the natives in most of the islands visited. On Atiu he could obtain no supplies of water or fodder both of which were urgently required and except for a few coconuts no food was purchased. However, no water could have been obtained nearer than a mile from the coast. As the weather proved rather unfavorable and the provision of supplies uncertain Cook wasted no further time at Atiu, but lay under Takutea (called by him Otakotaia) a small island of coral sand 12 miles north of Atiu. He found no inhabitants on the island though it is often visited by natives of Atiu to obtain a supply of fish. A considerable quantity of coconuts and fodder for the live stock was obtained, but no fresh water.

Though the language of the Atiuans is more like Maori than Tahitian, Omai, a native of Huaheine, who was in Cook's vessel was able to understand it and soon learned that three Society Islanders were living among the Atiuans. These men told Omai that they were the remnants of an expedition 20 strong which set out from Tahiti for Raiatea. Strong winds blew them out of their course and after drifting about for a number of days they came in sight of Atiu. All but three of them had succumbed to exposure, hunger, and thirst. The survivors had been well treated by the inhabitants of Atiu, they had become incorporated in the island society and refused the offer that was made to take them back to their own country. They must have been on Atiu for more than ten years for they had no knowledge of the visit of Captain Wallis to Tahiti in 1767. These Society Islanders have been so completely absorbed by the natives of Atiu that the story of their arrival is nearly lost. As a result of diligent inquiry in 1926, Mr. W. H. Scott, Resident Agent, discovered that a memory of the event still lingers and that the families of Tahitian origin are known.

After Cook's departure Atiu seems to have been unvisited until 1822, when the missionary John Williams arrived. A little before his coming a characteristic incident had occurred. A chief of Atiu named Akaina was living in Mauke, a neighboring island of small size. He became enamoured with the wife of an important chief of Mauke and at last managed to persuade the lady to live with him. Akaina was promptly killed but a native of Atiu then living on Mauke managed to paddle his small canoe to Atiu across the open ocean. As soon as he had told the relatives of the murdered chief about the events in Mauke an expedition was organized for revenge. Rongomatane, the leading chief, sallied forth with a fleet of canoes. Landing on Mauke he slaughtered the people in large numbers and not content with that he extended his voyage to Mitiaro, another little island 20 miles east of Atiu, and repeated the slaughter there. For years afterwards the miserable remnant in Mauke and Mitiaro lived in terror of their lives, for the Atiu natives from time to time descended on them and killed as many as could be found.

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When Williams landed on Atiu, he found the chief Rongomatane a willing convert to Christianity, owing to the persuasion of a chief from Aitutaki who was among Williams' party. Hearing of Mauke from the natives, Williams decided to go there. Rongomatane went with him. Great consternation prevailed among the people of Mauke but it was quickly changed to the joy of unexpected deliverance when they found that the dreaded chief had come in the spirit of Christianity. Since that time there have been no inter-island conflicts.

Even on Atiu itself there were occasionally fights. At the time of Rongomatane's absence on Mauke when most of the fighting men were away, the people of the Makatea region tried to gain control. These people comprised those who had been banished from the society of the island and in daily fear of their lives were eking out a miserable existence in the impenetrable rocky fastnesses. The women who had been left behind by Rongomatane, took up arms and the Makatea people had to retreat to their hiding places.

In connection with missionary enterprises Atiu was many times visited. In 1822 Mr. J. M. Orsmond sent two native teachers from Tahiti. John Williams who arrived in December of that year found them in a most pitiable condition "having been stripped by the natives of every article of property, suffering exceedingly from hunger." Visits were paid afterwards by the missionaries of Tahiti from time to time. In 1842 Rev. E. Krause arrived from America but he was unfortunate in landing on a part of the island where no natives were living. Rev. W. Gill first went to Atiu in 1843 and soon afterwards Rev. H. Royle paid visits, some of which were several months in length. For forty years after John Williams first visited the island, missionary efforts were in charge of native teachers. Until quite recent times all the missionary effort was due to the London Missionary Society—a Methodist organization; but lately the Roman Catholic Church, Seventh Day Adventists, and the Latter Day Saints have worked on the islands with greater or less success.

For many years missionary steamers, whaling ships, and occasional stray vessels called at Atiu at rare intervals. In recent years trading steamers call for copra, and bring such supplies as are needed. During the orange season fruit steamers pay a monthly visit and sometimes a vessel of the Royal Navy calls; but usually during the summer months, the so-called "hurricane season," no vessels appear.

POPULATION

Originally most of the natives of Atiu lived in the lower ground near the taro cultivations where terraces had been excavated for houses from the sides of the radiating spurs of volcanic rock. It may be noted, however, that Cook saw buildings on the plateau. The missionaries induced the people for their

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health and convenience, to live together on the plateau—the central flat part of the island which stands 280 feet above sea level.

At the present time all the people live on the plateau. The villages though quite near to one another have separate names and are subject to different chiefs of whom three are prominent at present: Ngamaru of Areora, Parua of Mapumai, and Rongomatane of Tengatangi.

The plateau is decidedly a healthy situation for Europeans and perhaps for the natives also. Certainly teaching and administration became far easier when the people were concentrated than when they were scattered in widely separated localities. The water supply, however, presented a difficult problem. The flowing springs that issue at the heads of most of the valleys are about 50 feet below the level of the plateau to which the water has to be carried. Within recent years the Government has constructed concrete tanks to store the rainwater that falls on the roofs of the village halls. As the rainfall is considerable and frequent this supply is sufficient at ordinary times for domestic wants. A curious attitude of the native mind comes to light in connection with this water supply. Those who live furthest from the tanks are jealous of those who live near them and may purposely leave the tap running so that all may fare alike in having to carry their water from the springs below the plateau rim.

Though all the natives live on the plateau most of them have small huts for temporary occupation near their cultivation grounds on the lower levels, and they spend much of their time there. Tribal boundaries are rigidly recognized in the settlements though the villages are almost continuous. As in Mangaia, Rarotonga, and probably in the other islands of the Cook group, the land is divided into sectors (*tapere*) separated from one another by radial lines proceeding from the central point of the plateau to the coast. Each family of standing has its own *tapere*. At the present time the population of Atiu comprises 925 natives and 10 Europeans.

VEGETATION

The small size of Atiu Island combined with its relatively low altitude prevent it from offering a great variety of station for plant growth. Consequently, the number of plant species is small and as would be expected, there seems to be no plant that is peculiar to this island. On the top of the low cliffs that face the sea the plant covering is that common to many Pacific islands. Proceeding inland, the species first seen are *Ipomaea lobata, Heliotropium anomalum,* and some hardy grasses. In most places, the first shrubby plant is *Scaevola koenigii,* commonly with *Cassytha filiformis* as a parasite, and the first tree is *Casuarina equisetifolia* (toa) associated with *Pandanus odoratissimus* (ara). The graceful foliage of the toa softens the harshness of the rocky coast. Sheltered from the blast of the salt-bearing

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winds by these plants a mixed vegetation including the magnificent *Barringtonia speciosa* (*utu*), is found. On the southwest side of the island the particularly huge *Barringtonia* trees with wide spreading branches completely satisfy all preconceived ideas of tropical luxuriance. Here and there the coconut palm is found but only in situations where it appears to have been planted though it grows freely in all parts of the coastal land.

Other prominent trees are the *Hernandia peltata* (*puka*) and the *Calophyllum inophyllum* (*tamanu*), a tree much valued for its canoe making timber. With these trees is a thick spreading growth of *Hibiscus tiliaceus* (*purau*), and of *Spondias dulcis* (*vi* apple). Likewise *Broussonetia papyrifera* (*aute*), and *Elaeocarpus rarotongensis* (*karaka*) are quite common. Here and there the wild banana, *Musa paradisaca,* is growing, but it is not common in Atiu. At the inner edge of the Makatea where the ground is kept wet by the waters of the swamp the *Inocarpus edulis* (*maupe*) appears as lofty trees with their characteristic sharply buttressed trunks. The waters of the swamp are shallow and are covered with a growth of reeds and rushes.

The volcanic ground is covered with a growth of the fern, *Gleichenia dichotoma* (*tuanui*), and with it a good deal of guava but both of these have a low growth because of the fires which often sweep across this ground. In the ravines through which the small streams run there is a varied growth from which the great *maupe* trees rear their crests but the predominant vegetation is a matted growth of hau (*au*).

On the Makatea are some plantations of coconut palms but these are more plentiful on the lower slopes of the volcanic ground. Oranges are grown on the Makatea. Taro is cultivated in the swamp near the volcanic slopes and in the lower part of the valleys. Bananas are planted on the lower parts of the volcanic slopes while many of the plantations of kumera and yams are on the volcanic plateau. Coconuts are also planted here, and there are a few oranges in the valleys.

The main industry of the natives is the production of copra, all of which is shipped in canoes at Taunganui and transported to steamers or schooners lying off and on. In July and August a few oranges are shipped to New Zealand.

BIRD LIFE

As elsewhere in Cook Islands, Atiu has few land birds. This is to be expected in view of the small size of the island, the small surface relief, the remoteness, and the large number of inhabitants who in the past have had a meagre supply of animal food.

A small swallow not found on Rarotonga or on Mangaia flits about the trees on the plateau. A woodpecker is rather common. A pigeon is to be found in most parts of the island especially in the wooded Makatea. The long

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tailed cuckoo is not uncommon in May. This migratory bird is found in New Zealand from October till February. It is noteworthy that with the exception of the pigeon the birds seen on Rarotonga, Mangaia, and Atiu, are all different though on Mangaia and Atiu some of them are very common.

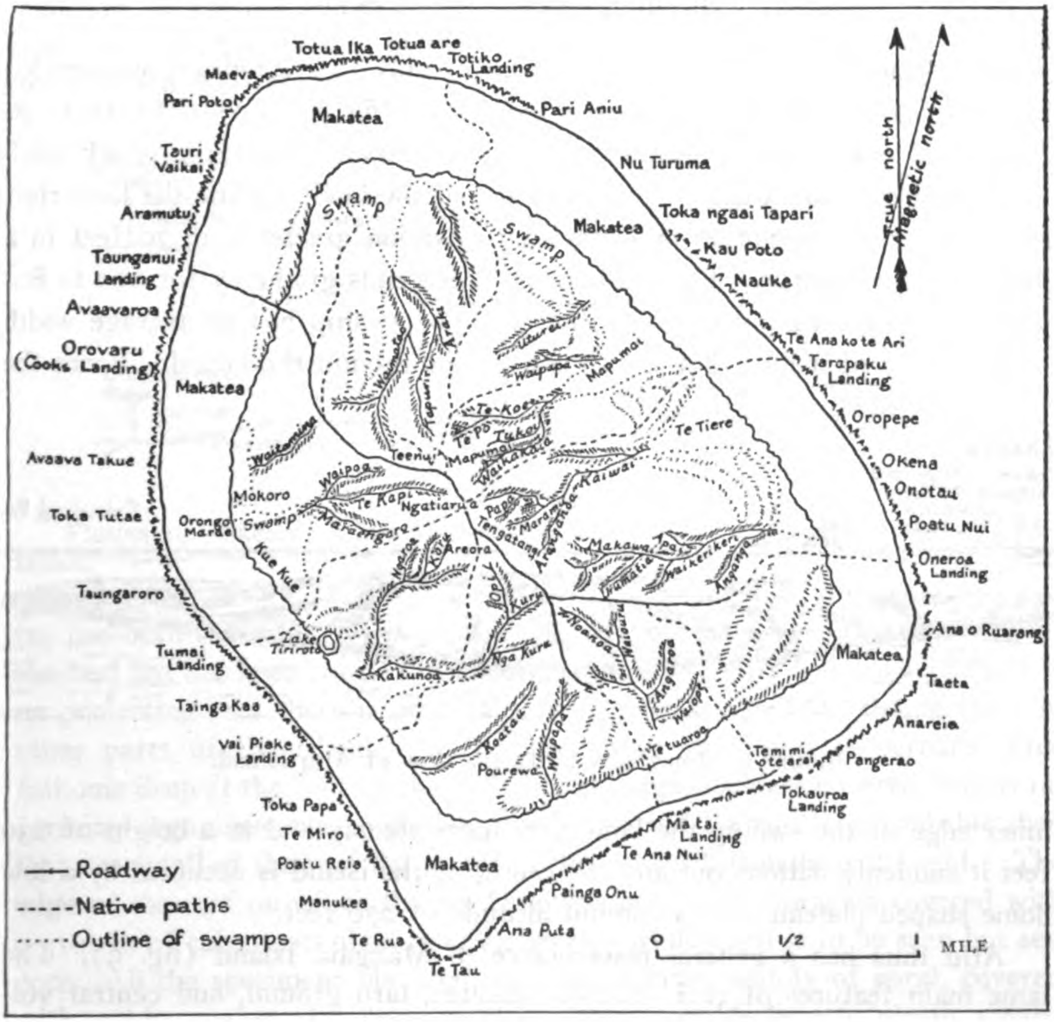

FIGURE 8.—Map of Aitu Island: Outline Survey by H. M. Connal (1911); physiographic features by Patrick Marshall (1927).

The water birds are not numerous. The duck (*Anas superciliosa*), the egret, and the blue heron of Atiu are the same as those seen throughout Cook Islands and in New Zealand. A dotterel common on Atiu, was not seen elsewhere. Only three kinds of sea birds were seen: the well known tropic birds

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(*Phaethon coerulea* and *ruficaudis*) and the frigate bird. No gannets and no petrels of any kind were observed.

It is a little strange that the native names that were given me by my guide Ngapaku for the duck and longtailed cuckoo: *morerau* and *arawi tangaroa* respectively, are different from those in use by the Maoris: *parera* and *koekoea*. The names of the other birds are the same in the two dialects.

PHYSIOGRAPHIC OUTLINE

The small island of Atiu with a circuit of only 12 1/2 miles is surrounded by a reef 50 to 100 yards from the shore. (See fig. 8.) Low cliffs 10 to 20 feet high front the sea everywhere but there are many recesses in which small beaches of sand are found. From the top of the low sea cliffs the land rises gradually, but does not at first reach an elevation greater than 70 feet in a distance of 300 yards. From this point it descends gradually for 600 to 800 yards, when a swampy tract is reached. The swamp has an average width of a quarter of a mile, but is not continuous around the island. From the

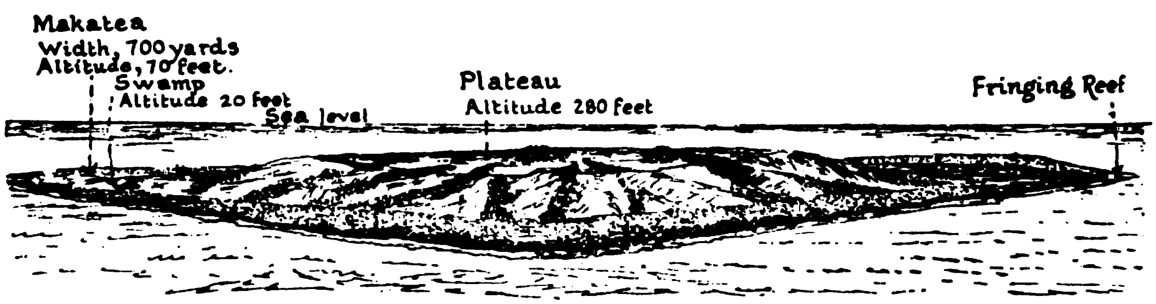

FIGURE 9.—Imaginary bird's eye view of Aitu Island.

inner edge of the swamp the land rises more steeply and at a height of 230 feet it suddenly flattens out and the center of the island is occupied by a low dome shaped plateau with a summit altitude of 270 feet.

Atiu thus has a general resemblance to Mangaia Island (fig. 9). The same main features of reef, strand, Makatea, taro ground, and central volcanic hill are present, but these features have not the same distinctness as on Mangaia. The reef in Atiu is in few places more than 50 yards wide; there is no marked line between the strand and the Makatea which rises no higher than 70 feet; the inland cliff which marks the descent from the Makatea to the taro ground is in most places hardly noticeable and the passage from one to the other involves but little change of level. The plateau which crowns the volcanic core of Atiu is much more extensive but is at a lower level than the corresponding feature at Mangaia.

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THE CORAL REEF

Except for a distance of a half mile at Te Pari Aniu the island of Atiu is entirely surrounded by a coral reef. Its margin is, however, close to the shore—in few places more than 50 yards distant—and the reef flat is frequently swept by the strong currents that arise from the breaking of the surf on the reef edge.

The shore line faces the sea in cliffs 10 to 20 feet high and are somewhat undercut by the sea which at high water and in rough weather breaks with some force at their base. It is, therefore, certain that a portion of the reef flat represents a shelf of marine erosion where the seaward fringe of the Maka-

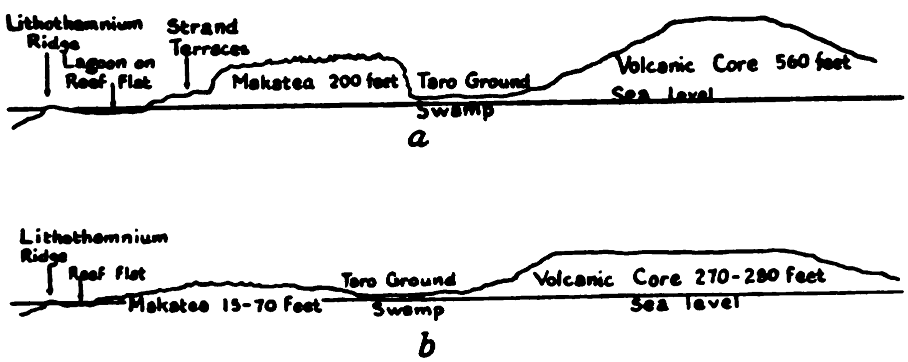

FIGURE 10.—Sketch sections showing general profiles: *a*, Mangaia Island; *b*, Atiu Island.

tea has been removed. It is probable, however, that a very small portion of the reef flat has been formed in this way, for at Te Pari Aniu, where there is no protecting reef there is no erosion shelf comparable with the reef flat in other parts of the island. At Te Pari Aniu the water is perhaps three fathoms deep at the foot of the cliff though large boulders covered with coral forming organisms can be distinquished here and there. It is probable then that nearly all of the reef flat is due to the outward growth of the reef. The edge of the reef on which the sea breaks is here as at Mangaia covered with a growth of calcareous algae, and *Polytrema* while coral is to be seen but seldom. All the specimens obtained, however, consist mainly of coral, covered with a thin coating of calcareous algae. It is possible here to obtain a measure of the rapidity of the growth of these algae. In 1910 a boat passage was blasted through the reef and since that time *Lithothamnium* has grown on the broken rock surfaces to an average thickness of half an inch. It seems, therefore, that these algae can form a crust of limestone one inch thick in 30 years.

The outer surface of the reef was closely examined from a canoe and from the edge of the *Lithothamnium* ridge at Taunganui on the northwest

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side of the island in fine weather. It descends rapidly but irregularly at first for a depth of 5 fathoms from which depth the surface of some large outlying bosses of reef extend upward about half way to the water level. The soundings increase quickly but the bottom could not be observed at a greater depth than 20 fathoms, 100 yards distant from the outer edge of the reef. The native fishermen, however, say that on all sides the sea floor slopes steeply to a depth of 100 fathoms, the limit reached by their lines. There is no anchorage for steamers.

Corals abound in all of the interstices of the outer side of the reef and among the corals there is a plentiful algal growth. On the tops of the out-

FIGURE 11.—Sketch of Captain Cook's landing, Orovaru, Atiu Island.

lying rocks as also on the surface of the reef a growth of algae alone is to be seen. Corals grow in abundance on the sea floor outside the reef but patches of sand are to be seen here and there. The sand areas become larger but coral heads are still abundant at the depth of 20 fathoms which was the limit of visibility.

THE MAKATEA

General Features

The Makatea (formation of raised coral limestone) in the Atiu Island has an average breadth of 1200 yards. It faces the beach as a small cliff, highest on the southern and eastern sides of the island but nowhere exceeding 20 feet in height. From the top of this cliff the surface continues to rise gradually and in most places uniformly until at a distance of 300 to 400 yards from the beach it is 70 feet above the sea level. From that point, the surface declines gradually until the Makatea terminates abruptly at the edge of the taro swamp 10-20 feet above sea level.

As at Mangaia, the surface of the Makatea on Atiu is highly irregular but

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the spaces between the projecting points of limestone rock are more completely filled in with red soil, especially on the inland side. As a whole, the Makatea on Atiu is a less formidable barrier between the coast and the interior of the island, than at Mangaia. In particular it does not rise as a cliff from the taro ground and there is no cliff on the beach side until the actual coast is reached. Though the small cliff that faces the beach is far more continuous, it is breached on the north and west sides of the island almost every hundred yards by a deep recess that offers a passage along a sandy floor, gradually rising to the surface of the Makatea. (See fig. 10.)

Mineralogical Composition

In the rock at Tumai landing, which is typical of that forming the seaward edge of the Makatea, the skeleton of organisms such as the corals and *Halimeda* originally composed of aragonite, are still composed of that mineral. Some of them, however, show the kind of change as described by David (13, p. 400) and by Skeats (29, p. 106). The original cavities of the coral skeleton are in places partly or wholly filled with aragonite of secondary origin in long prismatic crystals that are optically and crystallographically continuous with the crystalline elements of the coral structure. In a closely adjacent part of the rock, or even in the same microscopic preparation the material of the coral skeleton may be changed to calcite in the form of large plates, though dark lines may still show the margin of the original coral structure (Pl. V. *A, D*). In the same specimen relatively large rhombohedrons of calcite may appear in the central parts of the cavities. For all specimens studied it is thought that these crystals are formed from the prexisting crystals of secondary aragonite, because in these places the aragonite crystals have rounded terminations and have lost their clear definition. Whether or not the calcite rhombohedrons start in this way, they undoubtedly grow at the expense of the secondary aragonite, and before long completely fill the cavities in the coral which is then entirely changed into calcite. It should be borne in mind that all these different conditions can be seen in a single microscopic preparation of the rock. It seems that the aragonite of the actual coral skeleton changes into calcite before the secondary aragonite which fills the cavities. In the sandy portion of the rock from this outer part of the Makatea, which in the specimens actually obtained is not abundant, the various grains, whether composed of calcite or aragonite organisms, are cemented together by a deposit of the fibrous calcite crystals of secondary origin that have previously been described as formed on the *Lithothamnium* ridge at Mangaia Island (25, p. 15, Pl. III, 3). Here, however, the individual fibers appear rather coarser than on the ridge. It is also worthy of note that in one specimen from the *Lithothamnium* ridge of Mangaia a grain of coral in the sand had its cavities partly filled with secondary aragonite. In the rock from Tumai

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landing there is a large amount of *Halimeda* in the fine sand grains which form a portion of the rock. In a specimen collected from a spot 10 feet above sea level and 50 yards back from the beach, these *Halimeda* grains still retain their brownish tint. None of the specimens obtained from the Makatea at points more distant from the reef contains aragonite; all of this min-

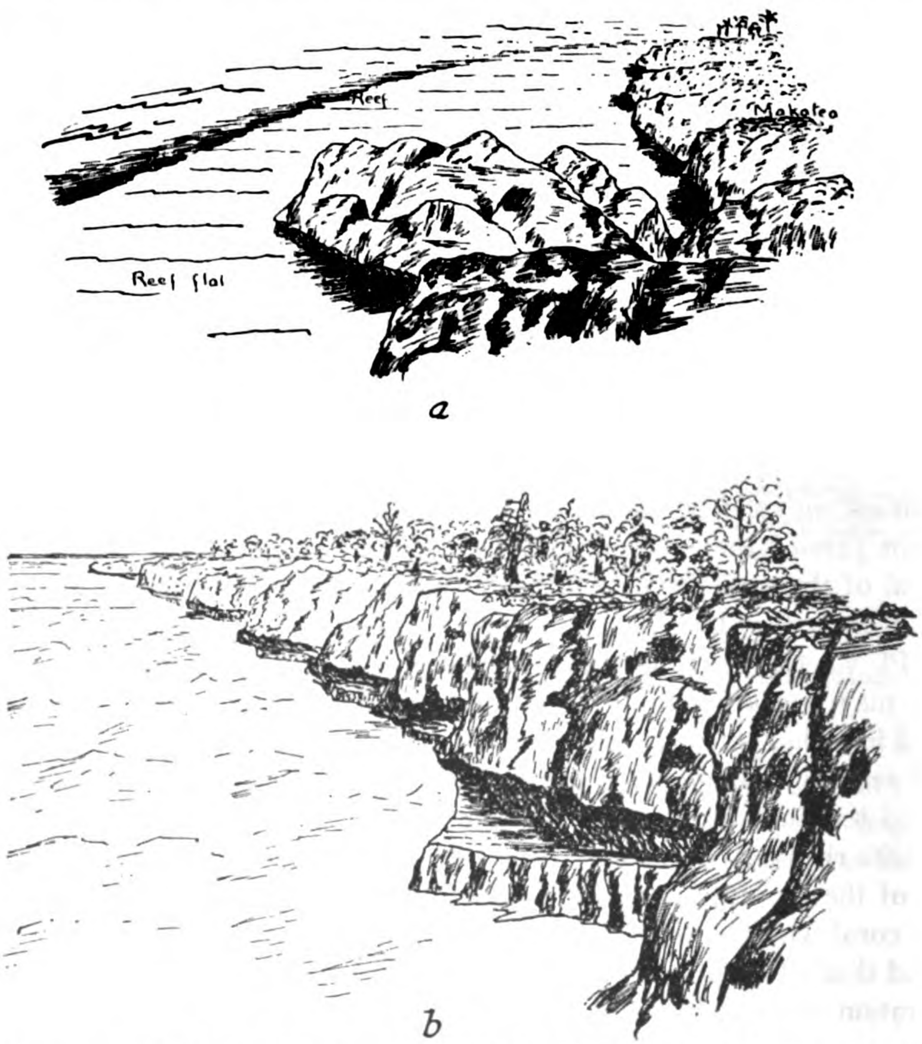

FIGURE 12.—Sketches of the coast line, Atiu Island: *a*, coast at Taunganui protected by a reef; *b*, coast at Te Pari Aniu, unprotected.

eral has been changed into calcite. As soon as the strand is left, *Halimeda* becomes far less common and the material of all the organic skeletons is recrystallised. It is hard to distinguish the fibrous growth of secondary calcite. This, on the whole, is far less distinct than in similar positions in Mangaia Island.

Soon after the highest point of the Makatea has been passed, some 400 yards from the beach, dolomitization begins. Whether this condition prevails

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in all parts of the island cannot be stated with certainty but it was found in at least four places: Taunganui, Oneroa, Te Miro, and Tumai, on the routes across the Makatea. (See Pl. V, *B, C*).

The change to dolomite proceeds very irregularly; in a single specimen one portion may contain 85.4 per cent of calcium carbonate and another no more than 68.6 per cent. Where the proportion of calcium carbonate is large it was found that the dolomite portion consists of the skeletons or organisms that were originally aragonite and were afterwards changed to calcite. Of these the corals are the principal organisms but some of the Foraminifera though originally calcite, have also been changed to dolomite. Thus while *Amphistegina* remains as unchanged calcite, the skeletons of *Gypsina* and *Operculina* originally also calcite, have been changed to dolomite. Though the cavities in the coral skeletons are generally entirely filled with calcite, the central portion of some is filled with dolomite in the middle of the calcite filling. (See Pl. IV, *D, E, F*).

In those parts of the specimen where the change is most complete, *Lithothamnium* is the only unchanged organism. It retains its original structure almost without change. This is a striking fact for it is now well known that the stony part of the tissue of *Lithothamnium* and its allies contains a higher proportion of magnesium carbonate than any other organism of the reef.

So far as can be seen in the rock which is now completely recrystallized, the only other situation in which calcite is found is in some of the spaces between the original grains of sand. Even in these places the calcite occupies the center of the original spaces only. As the inner edge of the Makatea is approached, the dolomitization of the rock is more pronounced and unchanged calcite is difficult to find (Pl. V, *E*). The infillings in the lacunae of a few coral skeletons show alternating layers of calcite and dolomite.

There is every reason to think that all of these mineralogical changes have taken place at or near the sea level. All the various conditions of deposition of secondary calcite and dolomite have been found in rocks that are now exposed at the surface while the nature of their exposure and the study of the physiography point emphatically to the opinion that the rock has never been submerged beneath any but a slight depth of water.

Comparison with Funafuti

All the mineralogical changes found in the limestone constituting the Makatea on Atiu are recorded in drill cores obtained at Funafuti atoll. It is of interest to notice the depth at which they occur. From the description by Cullis (10) the following list has been prepared:

1. 10-20 feet: the formation of fibrous calcite in the cavities was noticed in all of the bores.

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2. 20-90 feet: the percentage of magnesium carbonate increases with depth to a maximum of 16 per cent but no dolomite could be detected.
3. Deposit of secondary aragonite.
4. 100 feet: secondary aragonite changes to calcite.
5. 150+ feet: primary aragonite changes to calcite.
6. 50-637 feet: the material encountered is generally unconsolidated coral sand which it is suggested might be due to the solution of the aragonite in rock originally solid.
7. 637-1117 feet: the rock is dolomite except for one or two small masses of calcite.

To account for these variations in the composition of the material, the following explanations were advanced by the writers of the Funafuti report:

1. The fibrous calcite is thought by Professor J. W. Judd to have been deposited directly from solution.

2. The increase in magnesia in the upper part of the bore is ascribed to the leaching of the more soluble $CaCO_3$ from the rock in which magnesia was at first present in relatively small amount. (Skeats [30, p.199] suggests that as calcium and magnesium carbonates have solubilities that vary differently with changes of pressure, it is possible that at a pressure of two or three atmospheres a compound of the two carbonates is stable and tends to form readily when calcium carbonate is in the presence of the magnesian salts of sea water and carbonic acid gas.)

3. The deposition of secondary aragonite is ascribed to direct crystallization from solution in sea water.

4 and 5. No special explanation is given for these mineral changes.

6. The incoherence of the sandy material is thought to be due to the solution of aragonite.

7. It is suggested by Judd that the formation of dolomite is partly due to the leaching of some of the calcium carbonate, and partly to the greater abundance of the remains of organisms that have a relatively high percentage of magnesium carbonate in their stony material. Clark (7, p.448) regards it as most probable that the process of dolomitization is partly due to leaching and partly to the replacement of calcium carbonate by magnesium carbonate.

Comparison of the results obtained at Funafuti with those obtained at Mangaia and Atiu islands shows at once, as previously suggested by Skeats (30), that for many of these chemical changes it is erroneous to regard the depth of formation as a necessary factor. With the exception of the incoherent sandy material all of the conditions of limestone that have been recorded at different depths in the Funafuti bore have been found in the surface rock of Atiu Island. The great thickness of sand found in the bore was thought by the authors of the Funafuti report to have been originally solid coral rock

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and that from it aragonite had been removed by solution, leaving a mass of loose sand.

As compared with the records obtained at Funafuti a study of the materials from Atiu shows:

1. The deposit of fibrous calcite between the grains of sand takes place almost at the surface of the living reef at Atiu, also at Mangaia. In many places a thickness of only 3 mm. separates the actual surface of the reef from small cavities where the formation of this material is in progress. This portion is never more than a few seconds without a covering of water. The reef is continuously beneath water, except when the tide is at its lowest, and even then it is awash to every wave that breaks on the margin of the reef. Under these conditions concentration of calcium carbonate in solution by evaporation seems impossible, and its deposition cannot be explained in this way. It may be that the carbon dioxide required by *Lithothamnium* for its transpiration is derived from some of the calcium bicarbonate that is in solution in sea water and that the calcium carbonate thus liberated is deposited in the fibrous form. However, it would be expected that calcium carbonate formed in this manner would be deposited on the surface of the *Lithothamnium* rather than in the spaces between the small grains of sand. Calcium sulphate is, of course, present in relatively large quantities in sea water and under the conditions prevailing on a coral reef; the carbon dioxide liberated from the surface of the algae and other organisms by respiration may form calcium carbonate. The distinction between the fibrous carbonate formed in the presence of sea water and the rhombohedral form of all of the calcite that is deposited subsequently may have a large significance. The sand which is held by the algae and other organisms on the surface of the reef is surrounded by living and dead organic matter from which a great deal of carbonic acid gas is constantly being emitted. It is quite possible that as a result of the reaction between this gas and the calcium sulphate or chloride of sea water, calcium carbonate is produced and at once becomes crystallized in the fibrous form.

At Funafuti a deposit of fibrous calcium carbonate was found again in the lowest 300 feet of the bore. Nothing analogous to this was found in the dolomitic rock of Atiu Island, and no explanation of this occurrence at Funafuti is here attempted. At Mangaia and Atiu islands this fibrous form of calcite very soon changes into the irregular rhombohedral crystals and no subsequent development of the fibrous type of calcite structure was seen.

2. The higher percentage of $MgCO_3$ at a slight depth may be due merely to the prevalence of *Lithothamnium* and other organisms rich in $MgCO_3$.

3. The origin of the secondary aragonite in the lacunae of the coral skeletons may be the same as that of the fibrous calcite but the effect of the aragonite prisms in the coral structure is sufficiently potent to cause the carbonate

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to crystallize in the molecular form as aragonite instead of calcite, as elsewhere. The microscopic preparations that were made of the rock collected at Tumai landing show clearly that the aragonite of the coral skeleton changes into calcite grains of relatively large dimensions before the secondary aragonite has undergone any change (Pl. V, *D*). This observation is contrary to those made by Cullis (10) on the material from Funafuti, where the primary aragonite is more lasting than the secondary. Again in the rock examined from Atiu the calcite which fills the central portions of a few of the spaces is certainly secondary and has been formed from aragonite, whereas in the Funafuti material it is regarded as primary.

In the Funafuti report, no indication is given of the nature of the change that the fibrous calcite undergoes. It is merely stated that in various bores fibrous calcite was found at depths between 20 and 90 feet and again from 815 feet to the bottom of the bore. A study of specimens from the Makatea at Atiu proved that the fibrous calcite had undergone changes similar to those previously recorded for specimens from Mangaia. In both islands the fibrous form of the mineral rapidly changes into rhombohedral calcite. At first the rhombohedral crystals are quite small but as older and older rocks are examined the crystals are found to increase in size gradually. But even when all the elements of the rock have been recrystallized it is possible to see the limits of the original fibrous calcite for they are indicated by the slight cloudiness of the mineral where the fibrous matter has been replaced.

4 and 5. The change from aragonite both primary and secondary to calcite clearly takes place at the surface and has no relation to thickness of covering as was suggested in the Funafuti report. It seems to be simply a change from a less stable to a more stable form of calcium carbonate.

6. The unconsolidated coral sand which forms most of the Funafuti core at depths between 50 and 637 feet contains many organic remains that have become disintegrated by the solution of such substances as coral skeletons originally composed of aragonite. May it not be that this material was originally deposited as sand on the margin of a sinking reef, the actual site of which migrated slightly during long continued subsidence.

7. The development of dolomite from coral rock is, of course, a special problem on which there is still a considerable difference of opinion.

Dolomite in Pacific Islands

It is well known that dolomite is widely distributed in the raised coral rocks of Pacific islands. Dana (11, p.307) first recorded dolomite in a specimen from the island of Makatea. A second specimen, however, from the same island contained only 5 per cent of magnesium carbonate. In later years Skeats (30, p.118) showed that all the specimens collected by Agassiz from the raised coral reefs of Vatuvala, Yathala, and Kambara, were in reality dol-

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omites; that the rocks from Christmas, Mango, Namuka, and Euathere islands included both limestones and dolomites; and that only limestones were found on Niue, Vavau, Tongatabu, and Guam islands. In addition to these records, Elschner (14) reports dolomites at sea level at Anybodys Bay on the east side of Nauru Island and also on Ocean Island.

Information regarding the distribution of the dolomitic rock in the various islands is meager, or lacking. This is probably due to the fact that the specimens collected were not recognised as dolomites at the time. Skeats (30, pp. 71, 75) gives some valuable information based on field work by E. C. Andrews in Fiji, by Agassiz in Eua, and by W. C. Andrews in Christmas Island (Indian Ocean). For these islands, however, the distribution of dolomite is considered from the vertical, rather than from the horizontal direction, as was necessarily also done at Funafuti.

Chemical Composition of Makatea Rock

The following analyses were made of a number of specimens collected from the Makatea of Atiu Island:

	$MgCO_3$	$CaCO_3$
Crust on Lithothamnium ridge	73.09	14.53
Proportions in stony matter	83.42	16.59
Lithothamnium ridge, 3 ft. from surface	84.69	6.66
Oneroa, 1200 yds. from beach	61.30	40.10
Oneroa, 300 yds. from beach	98.80	1.42
Tarapaku, inner side of Makatea	59.10	40.20
Vai Piake, inner side of Makatea	57.51	42.86
Tumai, 700 yds. from inner side	97.73	2.15
Tumai, 1000 yds. from inner side	99.42	0.56
Te Miro, 300 yds. from inner side	85.41	13.67
Te Miro, in same specimen 10 cm. distant	68.64	31.12

By observing the effect of dilute hydrochloric acid and of dilute acetic acid on the specimens that had been analysed it was found that the extent to which dolomitization had proceeded could be roughly estimated without resorting to actual analysis. These tests showed that the rock on the inner side of the Makatea all around the island was generally converted into dolomite though here and there specimens were found that had undergone no change. The tests also showed a definite and gradual decrease in dolomitization from the inner towards the outer side of the Makatea, though at any one point, as shown by the analyses of a sample from Te Miro, highly magnesian limestone can be found in close association with material that is almost unaffected.

In order to study the details of this chemical change more closely a resort was made to staining. The method of staining with aluminium chloride and logwood as used by Lemberg (20) was found quite satisfactory for microscopic preparations. Staining with a deposit of silver chromate was also tried—a method which afterwards was found to have been used by Lemberg (20, p. 23) and strongly recommended by Cayeux (4, p. 183). This method

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proved particularly suitable for the study of hand specimens the surface of which had been ground down smoothly before the stain was applied. Surfaces treated in this way revealed the progress of dolomitization in a surprising manner. The extent to which the remains of different kinds of organisms were effected varied to such a degree that it was thought desirable to have a confirmation of the results by some other method that also would discriminate between calcite and dolomite. Of the acids tried, dilute acetic acid gave the most satisfactory result. When a smoothed surface of a dolomitic limestone was etched with this substance the calcite was at once dissolved but the dolomite was not touched. The distinction was extremely sharp and the result confirmed in very detail that obtained from the staining.

It is found that the first material to change into dolomite is the skeleton of organisms which originally is formed of aragonite. This agrees with the results recorded by the Funafuti expedition: though the associated statement that secondary aragonite changes more easily into calcite than the primary was not confirmed by examination of the Atiu specimens; in several tests the primary aragonite changed first. The changes in the corals are the most noteworthy. In all the partly altered rock the material of the skeleton had completely changed while the coral mud that fills all of the cavities remained quite unaffected. Thus in the compact magnesian limestone, a complete coral structure is revealed by etching and it stands out in relief (Pl. IV, *D*). The *Foraminifera* are differently affected: the genera *Gypsina, Polytrema, Amphistegina, Operculina,* and *Rotalia* can be distinguished in the rock. The tests of *Operculina, Polytrema,* and *Rotalia* are soon converted into dolomite while that of the other genera remain as unaltered calcite. In the very large number of each of these genera examined no exception to the rule was seen. Exactly the opposite condition was found in regard to the calcite mud with which the small chambers have been filled. These genera in which the skeleton has been changed to dolomite have their chambers filled with unchanged calcite mud. On the other hand those genera which retain the unchanged calcite skeleton have chambers filled with dolomite which is obviously derived from original calcite mud. The acid treatment confirms this in every detail. The dolomite skeletons stand out in well defined relief while the chambers are deep pits; the walls of the calcite skeletons have dissolved out while the dolomite in filling of the chambers stands out as minute rounded bosses. (See Pl. IV, *E, F.*)

No explanation of this remarkable difference is attempted here. It would seem, however, that it must be due to some inherent molecular structure in the calcite of the skeleton though that would not be expected to have any effect on the calcite mud with which the chambers are filled. Comparison may perhaps be made with the materials that were obtained from a depth

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greater than 850 feet in the Funafuti bore. There the deposition of calcite and dolomite alternated in the linings of many of the cavities.

Cause of Dolomitization

A good historical sketch of the views held by various geologists regarding dolomitization has been given by Skeats (30, p. 186) and by Clarke (7, pp. 480-86), but the authorities that they cite were for the most part not especially concerned with this phenomenon as related to the changes that have taken place in coral reefs. In reference to this particular aspect of the question, Dana (11, p. 307) has suggested that there may be a concentration of magnesian salts in lagoon water. Judd (13, p. 386) has laid emphasis on the possibility of the leaching of calcium carbonate which would leave behind a residue rich in magnesium carbonate. Clarke (7) tentatively ascribes the change to the combined action of leaching and of the presence of the preponderance of remains of organisms that originally contained a high percentage of magnesium carbonate in their skeleton.

Before any attempt is made to solve this problem it must be recognized that before dolomitization commences the rock has already become solid and resistant by the deposition of secondary calcite, some of which is first deposited as aragonite, in all of the spaces originally vacant. Cullis (10, p. 414) particularly mentions that the rocks between the depths of 1000 and 1070 feet at Funafuti show no sign of solution.

The two islands, Mangaia and Atiu, offer a great contrast so far as the distribution of dolomite is concerned. In Atiu the highest portion of the Makatea is somewhat on the outer side of its median line; in Mangaia the highest part is at its inner edge (fig. 10). In my description of Mangaia (25) it was stated that judging from the composition of some 20 specimens of limestone from the Makatea no dolomite occurred on the island. Since then it has been found that dolomite is present on the outer side of the Makatea at Te Ara Toiro, in the southern part of the island, and probably at Kumukumu in the northern part, and at Opiu in the southwest part.

In Atiu Island, on the other hand, dolomitization is general and for the most part complete throughout the inner part of the Makatea. Actual determinations of the amount of lime and magnesia were made in comparatively few places and the general statement is based on tests made by placing a drop of dilute acetic acid on the surface of specimens of the rock from a number of localities. The action of the acid had first been tried on the surface of specimens in which the amount of lime and magnesia had been estimated and it was found that the activity of the reaction gave a definite indication of the amount of magnesium carbonate in the specimen. This test showed that the extent of dolomitization decreased rather rapidly as the Makatea was crossed from its inner to its outer side. When the highest point of the encircling ring

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of Makatea was reached, that is, about two-thirds of its width from its inner margin, it was found that the amount of magnesia was as low as that in the material of the living reef, and that this condition extended to the outer edge of the Makatea. In other words, the outer third of the Makatea ring is formed of unchanged limestone while the inner two-thirds is formed of dolomitic limestone which is nearly pure dolomite at the inner edge of the Makatea but contains a gradually increasing percentage of calcium carbonate as the inner edge is left behind, and contains hardly any magnesium carbonate when the highest point of the Makatea has been reached.

It seems that these facts may lead the way to an understanding of the conditions that promote the change from the limestone of a coral reef to dolomite. At Mangaia, after the last movement of elevation, the base of the Makatea was for a long time subject to the wash of the sea water; until the reef had grown outward to a considerable extent. At Atiu the inner side of the Makatea was submerged for a long period which continued while the coral reef which now constitutes the Makatea grew outwards 500 yards; for at this distance from the beach it now has its greatest elevation. While the reef was growing outward a shallow lagoon was formed between the reef edge and the shore. The landward part of the reef which was formed first and afterwards became the floor of the small lagoon was subject to rapid circulation of water from the surf that broke over the reef edge which all the time was slowly extending seawards.

The dolomite at the foot of the outer edge of the Makatea at Mangaia was also subject to the circulation of sea water for a lengthened period. Here the rapid uprise of the island which was responsible for the outer cliff face of the Makatea would have raised some of the marginal growing surface of the reef from a depth of 15 fathoms to sea level. The organisms that were growing there would have been killed by the surf in their new station; the limestone of which their skeletons were formed would be subject to the constant action of the surf while the reef margin slowly grew outward at the new level.

On the other hand, since the inner edge of the Makatea is its highest part, no portion of the surface of the rising reef would be subject to the prolonged action of the circulating sea water during elevation. The lagoon separated from the sea by the gradual elevation of the Makatea would contain water almost still and of less salinity than sea water. This condition would obviously not permit the formation of dolomite from the limestone on the surface of the inner cliff of the Makatea if the circulation of sea water as suggested is the true cause of the change.

This explanation of the origin of dolomite by mere circulation of sea water at surface pressure in oceanic islands cannot be applied to the rocks studied by Skeats (29) because of the lack of accurate knowledge of distri-

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bution of the rocks and of the geological history of the islands in which they are found. This remark applies also to Funafuti where nothing is known of the areal distribution of the dolomite and for which information as to the vertical distribution is restricted to the results obtained from a single bore.

Soil

All the spaces between the projections on the rough surface of the Makatea are filled with a red earth at Atiu to the same extent as at Mangaia, forming a soil of great fertility. Its composition is shown in Table 3, which includes analyses of similar material from Mangaia and other islands.

TABLE 3. ANALYSES OF MAKATEA SOILS

	1	2	3	4	5
SiO_2	9.80	8.84	2.23	5.0	5.0
Al_2O_3	23.85	19.70	9.25	2.5	25.9
Fe_2O_3	25.13	31.71	4.15		7.4
CaO	2.75	1.60	30.36	32.5	
TiO_2	5.42	5.10			
P_2O_5	2.55	2.48	27.37	39.0	38.5
Loss on ignition	30.60	30.80	25.34	20.0	20.0
Total	100.10	100.26	98.70	99.0	96.8

1. Makatea soil from Taunganui, Atiu Island. Sample from near the road 600 yards from the beach. A sample from Vai Piake contained 4.47 per cent P_2O_5: Marshall (this paper).
2. Makatea soil from Mangaia: Marshall (25, p. 23).
3. Phosphate deposits from Walpole Island: Wright (39, p. 93).
4. Soil from Murray Hill, Christmas Island: Andrews (1, p. 291).
5. Phosphatized rock from Clipperton Island: Teall (34, p. 231).

To account for this material is difficult. The first explanation that comes to mind is that this soil has been derived from volcanic ash spread over the Makatea by volcanic action, and subsequently changed by laterization. But this explanation is unsatisfactory. In the first place the summit plateau of Atiu, the form of which is due to marine planation, must have been developed before the Makatea was in existence. If a depression sufficient to permit the planation of the summit had taken place after the Makatea had been formed, the long continued wave action would have covered the Makatea with material derived from the plateau, and would have filled all of the depression now occupied by the swamp. Again volcanic activity of an explosive nature would certainly have spread out the fine grained products unevenly, whereas the soil is distributed evenly over the Makatea though it is rather thinner on the outer than on the inner portion, especially at Oneroa. This explanation also fails to account for the high percentage of phosphoric acid.

The only explanation that seems to hold is that the soil represents the accumulated excrement of water birds, especially of duck. The widely ranging *Anas superciliosa* is found on the island and was at one time probably

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abundant; for during the period while the outer third of the Makatea was being formed, a large area of brackish water stood between the Makatea and the volcanic core. As pointed out in the account of Mangaia (25) the excreta of the duck contains much inorganic matter, which in the course of ages might accumulate to form a thick deposit. It is known that the huge deposits of calcium phosphate at Nauru, Makatea, and other islands is derived from the excreta of sea birds, and it is thus reasonable to assign the red earth of the Makatea at Atiu to this source.

Palaeontology

The general conversion of the material of the inner part of the Makatea into dolomite has naturally obscured to a great extent the characteristic features of the organisms of which it is composed. However, the outlines of many of their skeletons can still be distinguished in the thin dirt line which so persistently surrounds the "ghosts" of the fossils.

No remains of *Lepidocyclina* could be found though it is almost certain that such structures could be recognized even in the most dolomitized rock. The few pieces of relatively unaltered rock found in the inner portion of the Makatea contain a good deal of *Gypsina communis*. This species occurs also at Mangaia, but only in the outer part of the Makatea. Though a slender basis for correlation, the presence of this fossil in corresponding positions on the two islands suggests that the inner part of the Makatea at Atiu is approximately the same age as the outer part of this formation at Mangaia. At Atiu *Operculina* and *Amphistegina* are common; *Rotalia* is not rare; *Polytrema* is found everywhere; *Lithothamnium* is abundant, though less so than at Mangaia; *Halimeda* is rare. Corals make up a large portion of the rock and echinoid remains are everywhere to be seen. The material of the small cliffs on the coast is not of great age; in some places the aragonite of the corals is unchanged, and *Halimeda* retains its brownish tint in sections.

The evidence points to the probability that coral reef growth began in the early Pliocene and has continued without interruption till the present day.

Caves

The Makatea at Atiu Island is perforated by numerous caves some of which are as much as 500 yards in length. Several of them have been used for burials, which on occasions have been disturbed by Europeans. This has annoyed the natives, who, fearing vandalism, refuse to allow visitors to enter some of the caves. It is said that at one time during local fighting, a whole tribe took refuge in one of the caves and after wandering about in it were lost, and never emerged, probably a grossly exaggerated story. In some of the caves stalactites are abundant. Huge specimens have been broken off, carried some miles and employed in building the platforms in front of the houses of

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chiefs. They have been used also in the construction of the walls of some maraes. Where thus used, they have been merely piled one on top of another in horizontal positions without any attempt at shaping. Some large stalactites were seen on the central plateau in the village of Tengatangi. In transportation these huge pieces were tied to saplings and carried by large numbers of men. There is no indication that the stalactites were used in building the more elaborate structures such as those for which the basaltic columns at Kusaie Island were employed. In fact, throughout the Cook Islands no attempt was made to construct permanent buildings or fortifications except at Arorangi, Rarotonga, where some large phonolite boulders have been roughly piled together for defensive purposes.

The cave most easily accessible is Taketake, situated on the southwest side of the island near the track to the Vai Piake landing. This cave is entered from the surface of the Makatea at a point about 500 yards from its inner edge, where an irregular opening some 25 feet deep may be descended by means of a ladder. Within the cave stalactites and stalagmites are greatly developed. The roof of the cave must be near the surface of the Makatea for its highest point is not more than 75 feet above sea level. In one or two places, daylight can be seen through crevices in the roof. The floor of the cave is very uneven and in places is slightly terraced. No water flows on it. In places on the floor are a number of small rounded nodules of aragonite, ¼ to 1½ inches in diameter, somewhat vesicular, and concentrically zoned. Their surface is slightly rough, partly due to the projecting ends of small crystals and partly to irregular intersecting crevices. These aragonite nodules are somewhat irregularly arranged and only a few are attached to the floor. They do not seem to be related to the formation of stalactites. They lie on a wet floor but at the time of my visit though wet all over, they were not wholly immersed in the water. They are all stained with iron oxide derived from the soil that covers the surface of the Makatea. The cave was visited at the end of the wet season. It is possible that its floor is dry during the dry season, and that the nodules are formed from the calcium carbonate that had been in solution in the water that covered the floor.

Taketake cave may have been an original passage in the reef. In the reef that now surrounds the island many fissures extend almost from the margin of the reef to the shore line. Though at the surface these fissures are nearly closed by the growth of reef forming organisms, at a greater depth many of them open out into large spaces. It is probable that whatever may be the origin of these fissures the growth that takes place on their floors and sides is much slower than that on the roof, or on the surface of the reef. On the whole the fissures seem to have their maximum development on those portions of the reef where the sea is heaviest.

It was expected that the caves would prove to have been formed by the

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dissolving action of percolating water, or by streams, and it was a surprise to find little or no evidence for this origin. The floor of the cave seems to be a surface of deposition rather than solution, and no evidence could be found that there had at any time been a flow of water through it. The floor of the cave seems to be at a higher level than that of the water in the swamp.

At Ivirua, Mangaia, a cave 100 feet below the surface of the Makatea, seems to have been a channel through which water passed outwards from the old lagoon when the water level was 30 feet higher than now. For a considerable part of its length, it is not more than 6 feet wide and 10 feet high, but its direction changes frequently and the floor rises and falls. The rocks on the sides of the cave are rounded and there are few stalactites. It is said that this passage leads out to the beach about 5 feet above high water mark. In form and appearance this cave at Ivirua is wholly different from the cave at Taketake, which has a high roof in places broken through, an uneven floor, and sides formed of angular rock.

THE SWAMP

On Atiu, the Makatea ends abruptly at its inner edge around the whole circumference of the island. At Kuekue it terminates in a cliff about 20 feet high and 150 feet long; elsewhere it rises gently.

But though the abrupt precipice which characterizes the Makatea of Mangaia Island is lacking, the boundary between the Makatea and the swamp is everywhere well defined. Inland from the Makatea, the even surface of the swamp is maintained for varying distances to the foot of the volcanic ground, and in places extends for a quarter of a mile into the valleys of the small streams that flow from the central plateau.

In many places, especially on the south side of the island, the spurs of the volcanic ground extend to the edge of the Makatea, but even in these places they sink to the level of the swamp water before the Makatea is reached. These spur ends provide convenient routes for the native paths which lead from the volcanic ground to the Makatea, and on to the beach. In the southern part of the island, the swamp is represented only by a slight depression, in which bananas are grown. In those parts of the swampy ground where the water in the streams flows sufficiently to prevent stagnation, the conditions are favorable for taro cultivation. Some of the ground is used for that purpose, generally that on the inner side only, near the points where the streams enter the swamps. Otherwise the swampy ground is waste land, covered with a growth of rush and other water weeds. The surface of the swamp is 20 to 30 feet above sea level. In the wet season the swamp contains considerable water, but the small Lake Tiriroto is the only permanent sheet of water with a surface free from growth of weeds. It is said that in

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rough weather salt water is sometimes driven from the reef into the lake through subterranean passages.

There are no conspicuous sink holes by means of which the water of the swampy area can pass into channels through the Makatea. The wetness of the swampy ground shows that channels through the Makatea afford less easy passage for the outflow of water than they do at Mangaia Island.

THE VOLCANIC CORE

Only in a few places is the volcanic ground in Atiu directly connected with the limestone of the Makatea. Over most of the circuit of the island swampy ground intervenes between the two.

The summit of the volcanic ground is a nearly flat area of two square miles at an altitude of 270 feet above sea level, though its peripheral portions are 56 feet lower than the central part. This plateau is deeply dissected by valleys which radiate outwards to the coast line. The head waters of streams flowing to opposite sides of the island have left but a narrow ridge between them. Remnant lobes of the plateau of considerable size separate the middle courses of the radiating streams, and near the circumference of the plateau attain a considerable width.

As compared with Mangaia where only a small portion of the plateau remains, it is obvious that the plateau on Atiu is still in the early stages of dissection. The streams have eroded deep, steep-sided valleys. The larger valleys have flat floors which extend a quarter of a mile back from the apices of the spurs.

Notwithstanding the transporting power of the heavy tropical rainfall, the weathering of the rock has proceeded far more rapidly than its removal. The explanation of this may be the same as that which was offered for similar conditions in Mangaia: the matted rhizomes of *Gleichenia dichotoma* on the ground combined with the dense canopy of its foliage protect the soil to such an extent as to almost prevent the removal of the surface material by rainfall; at the same time the growth of the *mape* (*Calophyllum inophyllum*) in the stream valleys protects their floors so effectively with its matted roots that erosive action of streams is almost stopped.

The weathering of the basalt is apparently the same as that in Mangaia where it has produced a partial laterization of the rock.

No patches of limestone were found anywhere on the volcanic rock and their absence as well as the absence of fossil shells justifies the opinion that the uplift of the plateau from the level at which it was formed by marine erosion took place so soon after its development that no marine life had migrated to it, and no masses of limestone had been formed.

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Small terraces are to be seen on the flanks of the volcanic hill. The one most strongly developed stands at the same altitude as the highest part of the Makatea (70 feet above sea level) and is more or less general on the distal portion of the spurs all around the island. A less pronounced terrace appears in places some 30 feet lower. These terraces must mark levels of marine erosion as they are far more extensive and continuous than those that have been excavated by the natives to serve as platforms for their houses. The lower terrace, which is extremely fragmentary, marks the sea level before the old fringing reef, now the Makatea, began its growth. The upper one marks the level of marine erosion at the period of maximum subsidence when, perhaps owing to relatively rapid downward movement, the reef, for the time, did not provide protection for the coast sufficient to prevent it from suffering from wave action.

The apparent absence of beach matter of organic origin on the slopes of the volcanic ground implies a considerable difference in the conditions that prevailed while the Makatea was being formed from those now existing at Huaheine and Raiatea islands, where there are fringing reefs or coral beaches as well as the barrier reefs. In parts of Tahiti, however, and on the coast of north Queensland, marginal fringing reefs are absent, and there are no coral beaches for considerable distances along the coast line. It may be that where the coast line provides much inorganic detritus there is no marginal growth of coral.

There is no indication of any eruption of the central volcano after the growth of the Makatea had begun. In no place do the volcanic spurs invade the Makatea, nor do they spread out where they reach its margin. Furthermore, the surface of the Makatea is not covered with scoriaceous volcanic matter as Chubb (6, p. 309) found at Rurutu Island. The red soil on the surface of the Makatea has quite a different origin.

As shown on the map (fig. 8), the plateau with its lobes between the stream valleys extends over all the central part of the island; it is possible to walk for a distance of two and a half miles north to south, and of two miles east to west on almost level ground. This level area was originally, and in large part still is, covered with the fern *Gleichenia dichotoma* through which rise a considerable number of toa trees; which frequent burning of the vegetation on the plateau prevents from attaining any large size. The rocks of which this plateau is composed are deeply weathered and the material has been converted into a dark red, unctuous clay which in wet weather is particularly adhesive. In the clay small nodules of ilimonite are common, and manganese oxide is also found. Here and there, particularly on the northeast slopes of the island, some roots of the *Gleichenia* fern have become silicified, but no large masses of flinty silica were found on the surface as in Mangaia Island.

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In places the paths that have been made by the natives in walking from their homes to their taro patches, or to the fishing grounds, have been washed out by the rain into deep gutters. Here and there, the structure of the plateau is revealed on the high banks even though the rock has been entirely changed. All the original rock seen is fragmentary and scoriaceous and in places the same structure is shown on the sides of the steep ravines that the streams have excavated in the plateau. The heads of these valleys are abrupt and in a few places unaltered rock may be seen in dikes. A dike at the bottom of the Waikakaia, and another in the village of Teenui, at the head of the Topuriri Valley, consist of rather coarse-grained basalt. In the marae visited by Captain Cook are some blocks of a fine grained basalt but their source could not be ascertained. It seems that all of the rock of which Atiu Island is formed is basaltic. No indication was found of phonolitic rocks that have such a wide distribution in Rarotonga, nor of nepheline basalts such as are found in Aitutaki.

DESCRIPTION OF ROCKS

All of the volcanic rocks found on Atiu have proved to be basalts. The ordinary type of rock illustrated by that in the dike near the source of the Waikakaia, is coarse-grained with large idiomorphs of a brown augite, some of which are conspicuously zoned, the outer zone having the higher extinction angle. Large idiomorphs of olivine are somewhat less abundant, but most of this mineral is changed to serpentine though talc is also present. The few phenocrysts of feldspar have an extinction angle, which shows that they have the composition Ab 35 An 65. The groundmass consists mainly of colorless augite with some microlites of feldspar and many euhedrons of magnetite. There are a number of round gas pores filled with secondary minerals. The lining of many pores is hyalite, perhaps with a little chalcedony, but the central portion is filled with calcite.

This rock has a specific gravity of 3.16, but is less basic than the coarse-grained basalts of Mangaia and Rarotonga, which contain no phenocrysts of feldspar. It would appear to fall in the group of "basaltes labradoriques" of Lacroix (19, p. 61) of a less basic composition than his ankaramites and oceanites.

The fine grained rock from the Orongo Marae, the exact origin of which is not known, is still less basic and comes near the "basalte andesitique" from the Marquesas as defined by Lacroix. The structure is that called "intersertal" by Rosenbusch, the augite and feldspar of which the rock is almost entirely composed of equal dimensions. There are some isometric idiomorphs of magnetite. The first mineral to crystallize was the magnetite, followed in

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turn by the few larger grains of augite, the feldspar laths, and the minute irregular augite, and feldspar with some minute grains and needles of magnetite.

As shown in the following analysis, the basalt from Atiu contains a relatively high percentage of silica and of lime. Similar rocks have been described by Lacroix (19) from the Marquesas and other Pacific islands.

	1	2
SiO_2	46.60	46.68
Al_2O_3	14.68	15.01
Fe_2O_3	9.82	6.35
FeO	4.61	5.44
MgO	5.08	4.30
CaO	10.05	9.84
Na_2O	2.14	3.13
K_2O	1.74	1.51
TiO_2	1.42	4.20
P_2O_5	0.36	0.47
H_2O	2.20	3.10

1. Basalt. Orongo Marae, Atiu Island: Marshall (this paper).
2. "Basalte andesitique" from Nukuhiva, Marquesas Islands: Lacroix (19, p. 42). Many other analyses of similar rocks are given in this paper by Lacroix.

GEOLOGICAL HISTORY

Like many other islands in the south central Pacific, the first appearance of Atiu Island above the surface of the water was due to volcanic action. The result of this activity was the formation of an island which measured approximately 3 miles in diameter. At a time when the level of the ocean surface was 270 feet higher than now, or the floor of the ocean 270 feet lower, the island was composed of fragmental volcanic matter. As at Mangaia, wave action soon reduced Atiu to the condition of a shoal. Slow elevation then took place until the sea level was perhaps 50 feet lower than now, and there was considerable atmospheric erosion of the platform that had been formed by marine planation.

After this had proceeded to a considerable extent, the formation of a coral reef began. At the same time the volcanic slopes became covered with a thick mat-like mantle of *Gleichenia dichotoma* which held the surface together and prevented the removal of the clay which had been derived from the action of the atmosphere on the volcanic rock. The thickness of clay thus preserved from removal, in time became considerable. The fringing reef of coral which began to develop after the erosion had produced most of the stream valleys, soon protected the shore line and gradually extended outwards.

Slow subsidence continued and as the coral reef grew outwards, each successive portion was higher than that interior to it. These relative actions continued until the reef had become 600 yards wide. The movement was then reversed, the negative condition being apparently succeeded without any in-

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terval by positive, though the movement was extremely slow. The reef was able to maintain its outward extension without modification while positive movement continued. It has a surface, which, though irregular, on the average slopes seaward at a small angle.

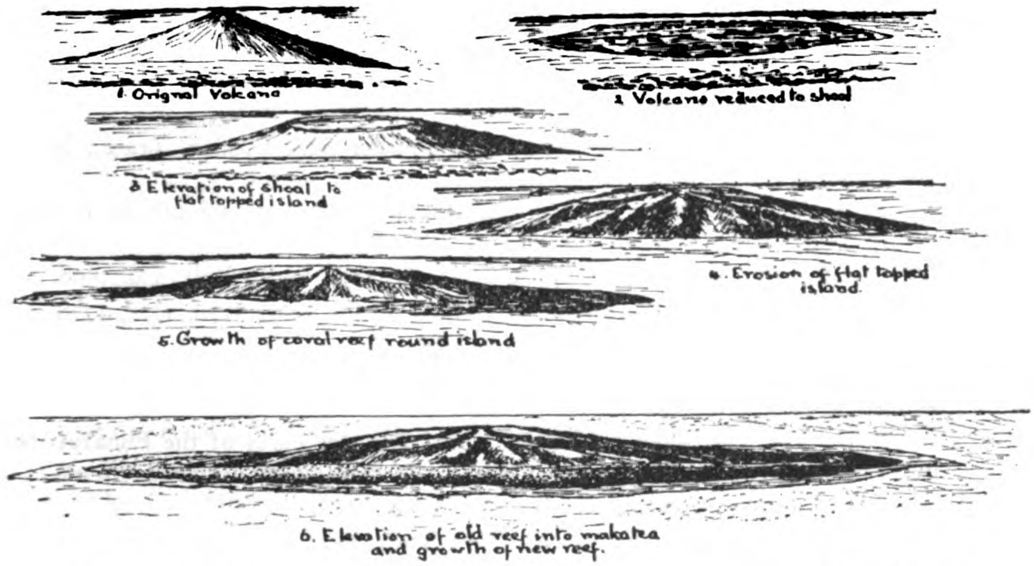

FIGURE 13.—Sketches illustrating the geological development of Atiu Island.

For a considerable time still-stand conditions then prevailed and the attack of the sea was maintained at a constant level, and has now eroded a small marginal cliff which overlooks the reef flat.

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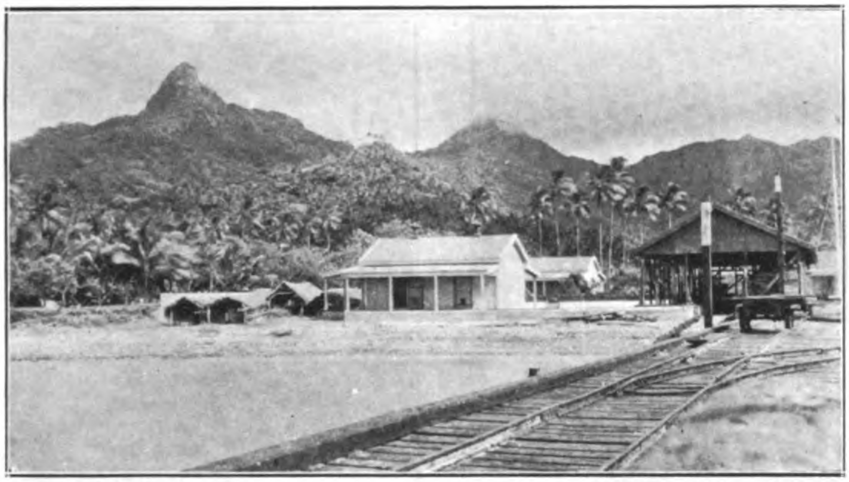

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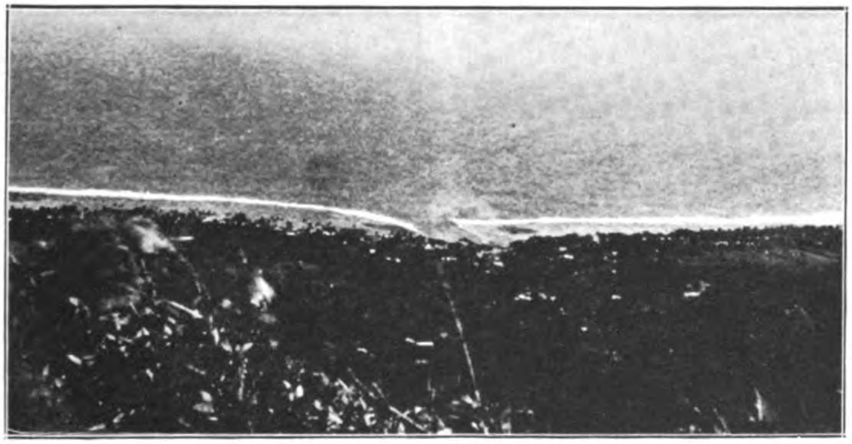

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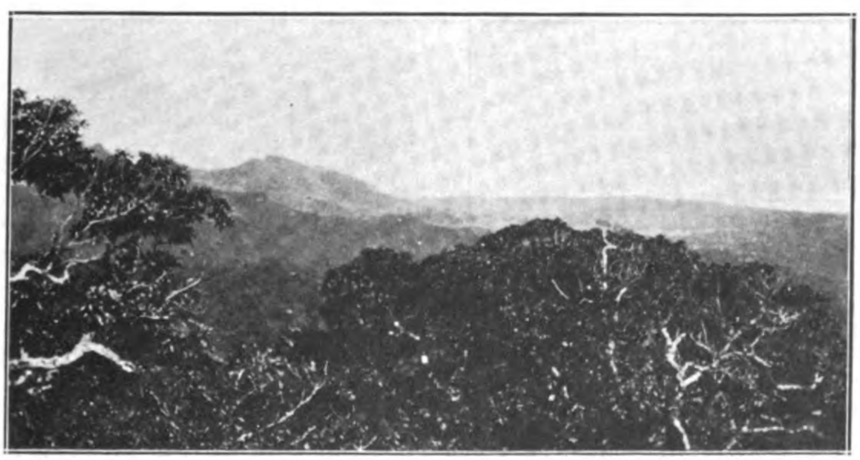

C

VIEWS OF RAROTONGA: *A*, WHARF AT AVARUA, HIKURANGI PEAK AND TE MANGA (CLOUD-CAPPED) IN BACKGROUND; *B*, FRINGING REEF AS SEEN FROM MAUNGATEA BLUFF (ALTITUDE 1,200 FEET); *C*, LOOKING WEST FROM MAUNGATEA BLUFF.

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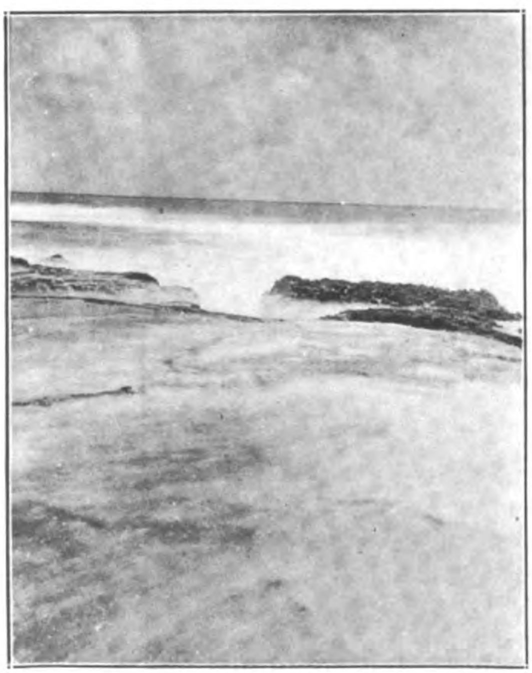

C

D

VIEWS OF RAROTONGA: *A*, BLACK ROCK (TUORU); *B*, BEACH AT TITIKAWEKA; *C*, EDGE OF REEF AT NGATANGIIA SHOWING LITHOTHAMNIUM RIDGE; *D*, TARO SWAMP, BREADFRUIT, AND PALM TREES WITH HIKURANGI PEAK IN BACKGROUND.

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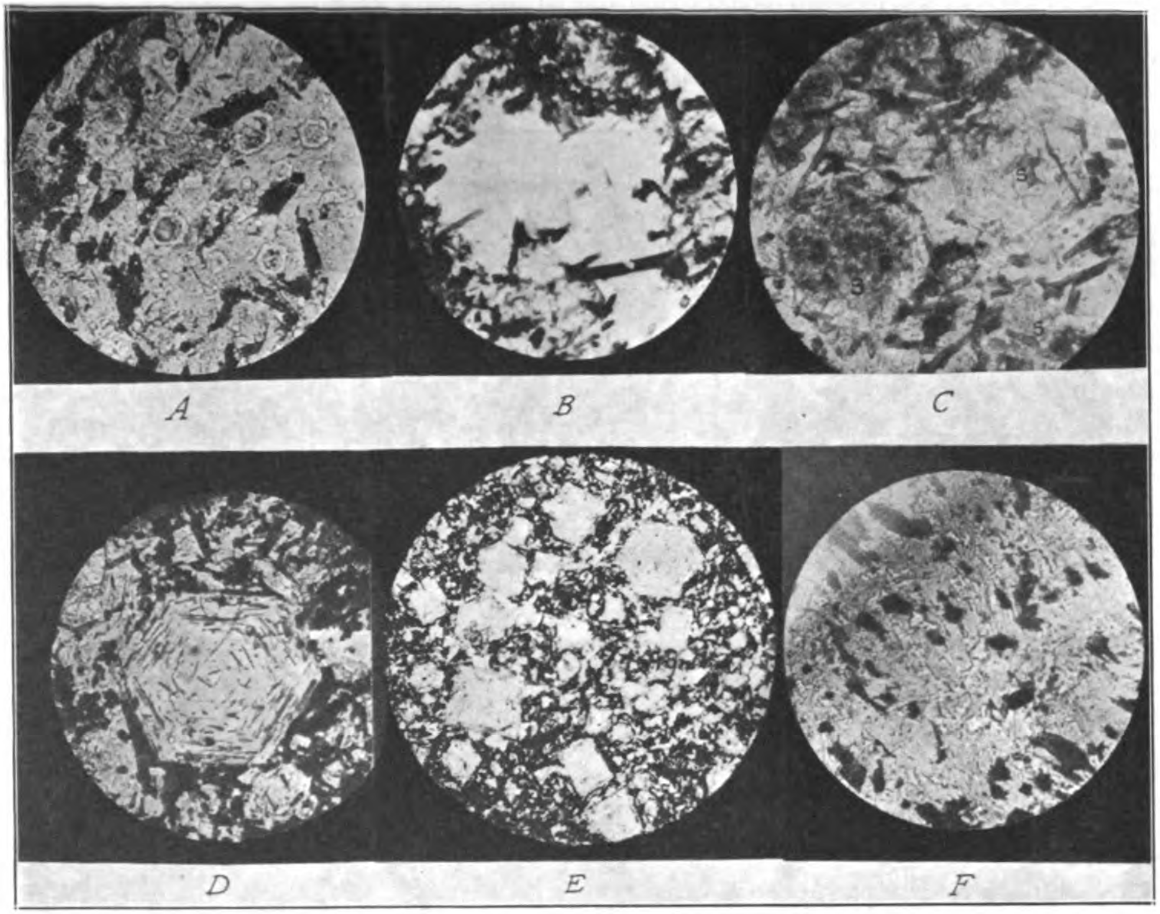

MICROPHOTOGRAPHS OF ROCKS FROM RAROTONGA: *A*, SODALITE PHONOLITE FROM RAEMARU; ISOMETRIC CRYSTALS OF SODALITE WITH LOW REFRACTIVE INDEX, NEPHELINE CRYSTALS FORM CLOUDY PATCH NEAR CENTER, DARK MINERAL IS AEGERINE, THE REMAINDER FELDSPAR, × 100; *B*, SODALITE PHONOLITE FROM MAUNGATEA; WHITE PATCH IS A ZEOLITE INTO WHICH PROJECT CRYSTALS OF AEGERINE, × 100; *C*, PHONOLITE FROM MAUNGATEA BLUFF, CRYSTALS OF SODALITES WITH CROWDS OF INCLUSIONS, × 180; *D*, PHONOLITE FROM TUKAVAINE, CRYSTAL OF NEPHELINE INCLUDING REGULARLY ARRANGED NEEDLES OF AEGERINE, × 100; *E*, NEPHELINITOID PHONOLITE FROM TUKAVAINE, NEPHELINE CRYSTALS CONTAINING MICROLITES OF AEGERINE, × 30; *F*, TRACHYTOID PHONOLITE FROM TAIPARA, SHOWING AREAS OF "GLASS" (AMELETITE) NEAR CENTER, DARK GRAINS AEGERINE, REMAINDER FELDSPAR, × 100.

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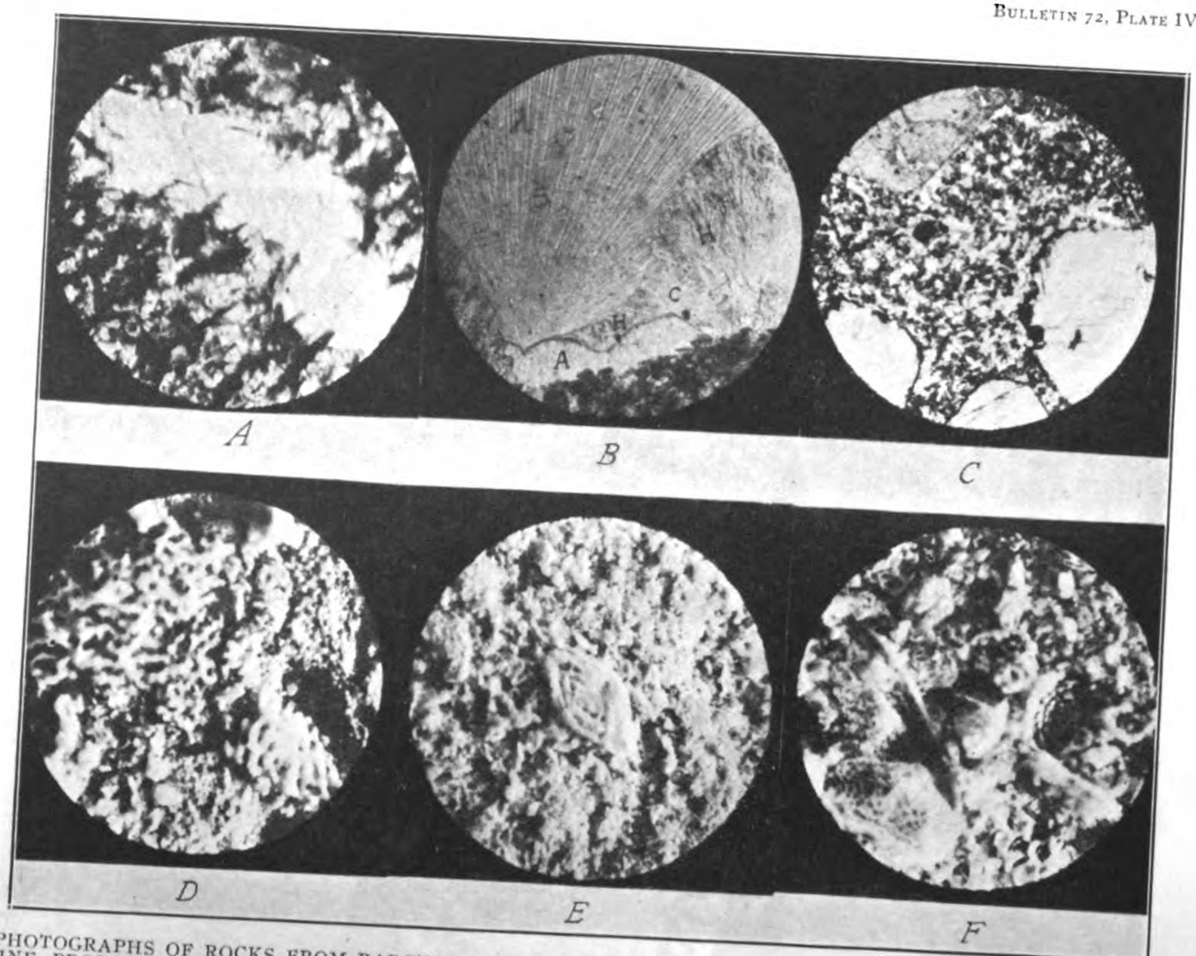

MICROPHOTOGRAPHS OF ROCKS FROM RAROTONGA: *A*, NEPHELINE PHONOLITE FROM MOUNT MAUNGATEA, NEEDLES OF AEGERINE PROJECT INTO AREA OF ZEOLITES, × 120; *B* ZEOLITES IN NEPHELINE PHONOLITE FROM SUMMIT OF MAUNGATEA: (*a*, ANALCITE; *c*, CHABAZITE; *h*, HYDRONAPHELITE ?; *s*, STILBITE ?; *r*, ROCK). × 180; *C*, ANKARAMITE FROM TUPAPA. THREE CRYSTALS OF OLIVINE AND ONE OF AUGITE IN A GROUND MASS OF FELDSPAR AUGITE AND MAGNETITE, × 30; *D*, LIMESTONE FROM TE MIRO, ATIU ISLAND, CORAL SKELETON CONVERTED INTO DOLOMITE, FILLING REMOVED BY ACETIC ACID, × 8; *E*, LIMESTONE FROM TE MIRO, ATIU ISLAND, DOLOMITIZED OPERCULINA, CALCITE REMOVED BY ACETIC ACID, × 8; *F*, LIMESTONE FROM TE MIRO, ATIU ISLAND, CHAMBERS IN AMPHISTEGINA (*a*) FILLED WITH DOLOMITE.

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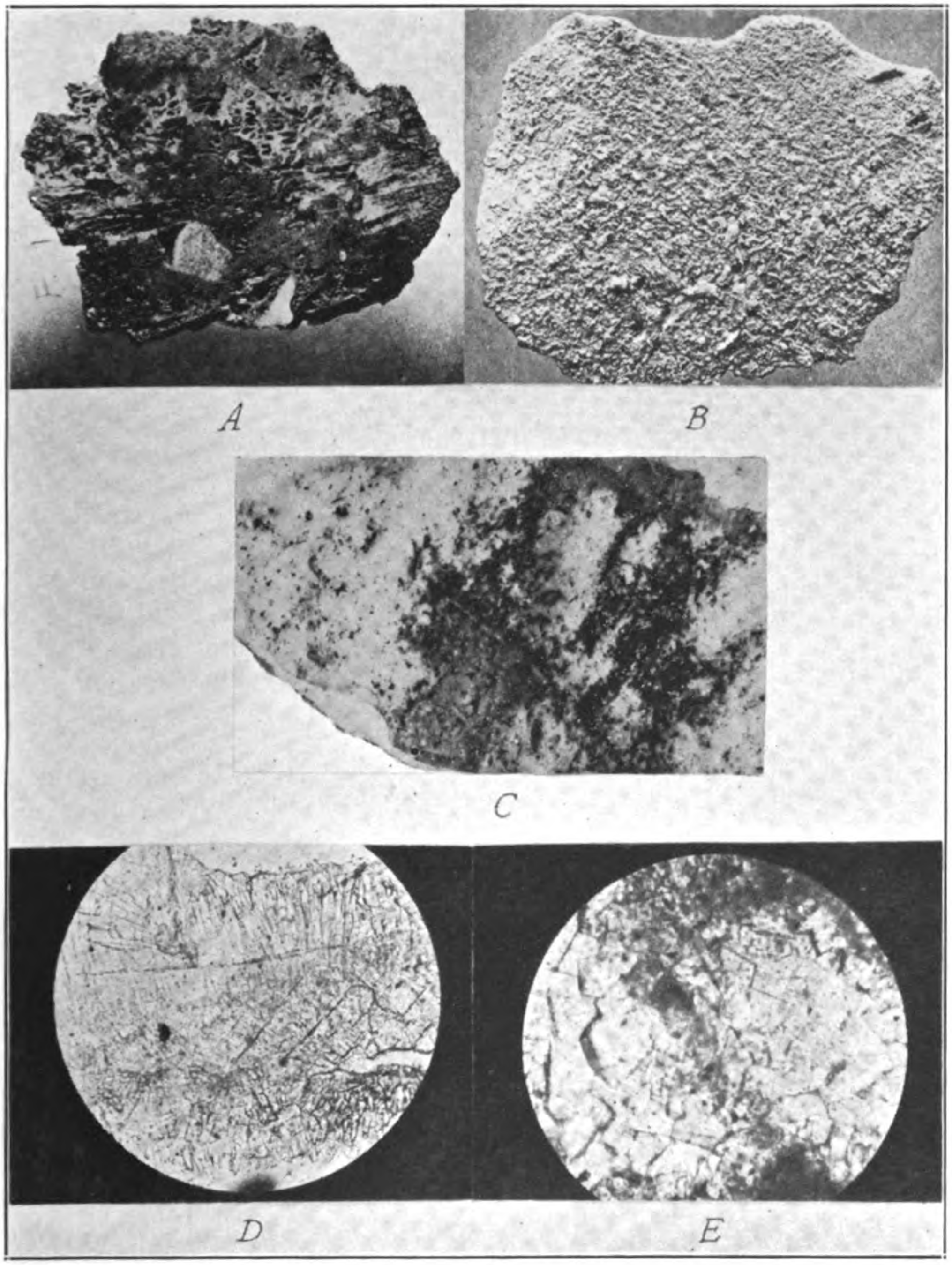

PHOTOGRAPHS OF LIMESTONE FROM ATIU: *A*, PARTLY ALTERED CORAL ROCK FROM TUMAI LANDING, STAINED WITH COBALT NITRATE; THE BLACK PARTS ARE EMPTY SPACES IN THE CORAL; THE GRAY, PRIMARY AND SECONDARY ARAGONITE; THE WHITE CALCITE, × 2; *B*, ROCK FROM THE MAKATEA 500 YARDS FROM TAUNGANUI LANDING ETCHED WITH ACETIC ACID. THE DOLOMITE STANDS OUT, × 2; *C*, MAGNESIAN LIMESTONE 600 YARDS FROM TAUNGANUI LANDING, SMOOTHLY SURFACED AND STAINED WITH LEMBERG'S SOLUTION. THE CALCITE IS DARK; THE DOLOMITE, WHITE, × 2; *D*, ROCK FROM TUMAI LANDING, CLEAVAGE SHOWS CENTRAL LAMINA OF CORAL TO BE CALCITE, SECONDARY ARAGONITE PROJECTS INTO THE CAVITY FROM EITHER SIDE, × 100; *E*, CORAL ROCK FROM THE INNER SIDE OF THE MAKATEA. RHOMBOHEDRA OF DOLOMITE PROJECT INTO AN ORIGINAL CAVITY, × 100.

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REMARKS ON PACIFIC FISHES

BY

VICTOR PIETSCHMANN

BERNICE P. BISHOP MUSEUM

BULLETIN 73

HONOLULU, HAWAII
PUBLISHED BY THE MUSEUM
1930

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Remarks on Pacific Fishes

BY VICTOR PIETSCHMANN

Since the publication of the comprehensive work by Mr. Henry W. Fowler (Fishes of Oceania: B. P. Bishop Mus., Mem., vol. 10, 1928), a number of undetermined fishes have been received at Bernice P. Bishop Museum. Some of them were obtained at the Honolulu Fish Market; some from various parts of Oahu, collected by Dr. C. H. Edmondson. The motor schooner *Lanikai,* fishing several times a year on the shores of the small uninhabited islands, Pearl and Hermes Reef, Laysan, and Lisiansky, brought fishes collected by Theodore T. Dranga. Small collections were sent in from outlying islands, where were working members of the Museum staff—Dr. Harry S. Ladd in Fiji, and Mr. Hans G. Hornbostel in Guam.

Four new species have been described and a number of differences and variations in fishes already determined have been noted. Many of these differences may be later recognized as characteristic of stages of growth or of local variety. It is of course impossible, with the limited material available, to make final observations. These notes are presented only as a basis for future work. I have also included remarks on some Hawaiian fishes found in old collections at the Vienna Museum, especially on an old specimen of *Hynnodus (Scepterias) fragilis* (Jordan and Jordan).

I am indebted to Bernice P. Bishop Museum for the opportunity of making these notes in connection with my work as Bishop Museum Fellow. Acknowledgment is due to many persons for their assistance in my work, especially to Miss Stella M. Jones for her assistance in arranging the descriptions in form for publishing.

Echinorhinus cookei, new species (Pl. I, fig. 1).

One adult male, 2033 mm. long. Head 5, caudal 5.2, greatest height of body 5.8, distance from tip of snout to base of pectoral 3.6, distance from pectoral base to beginning of ventral 3.7, from beginning of first dorsal base to tip of caudal 2.7, from second dorsal to tip of caudal 5.1 in total length.

Diameter of eye 10.9, interorbital same length as snout (2.5), breadth of mouth 1.8, depth of mouth 4.1, distance of nostrils 2.4, breadth of nostrils 10.4, distance from eye to tip of snout 2.4, from base of pectoral to tip of snout 5.2, length of first gill opening 4.9, of last gill opening 3.3, base of pectoral 2.9, of first dorsal 2.5, height of first dorsal (vertical distance from body to tip of fin) 4, of second dorsal 3.9, height of caudal peduncle (measured on end of base of second dorsal) 2.9, measured at beginning of lower caudal lobe 3.1, front edge of first dorsal 2, of second dorsal 2.2, of pectoral 1.6, of ventral 1.9, in head. Rear edge of pectoral 1.9, greatest breadth of pectoral 1.4 in front edge of pectoral, rear border of first dorsal 1.9, inner border of first dorsal 2.4 in front edge of first dorsal, rear border of second dorsal 1.8, inner border of second dorsal 2.5

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in front edge of second dorsal, first gill opening 1.5 in last. Distance of middle front border of mouth from tip of snout 1.5 in breadth of mouth, depth of mouth (distance of middle of rear border from a line connecting both angles of mouth) 4.1 in breadth of mouth.

Form of body moderately thick, toward tail becoming more compressed, forehead flat, snout pointed, tip of snout roundish. Mouth broad, moderately curved. One row

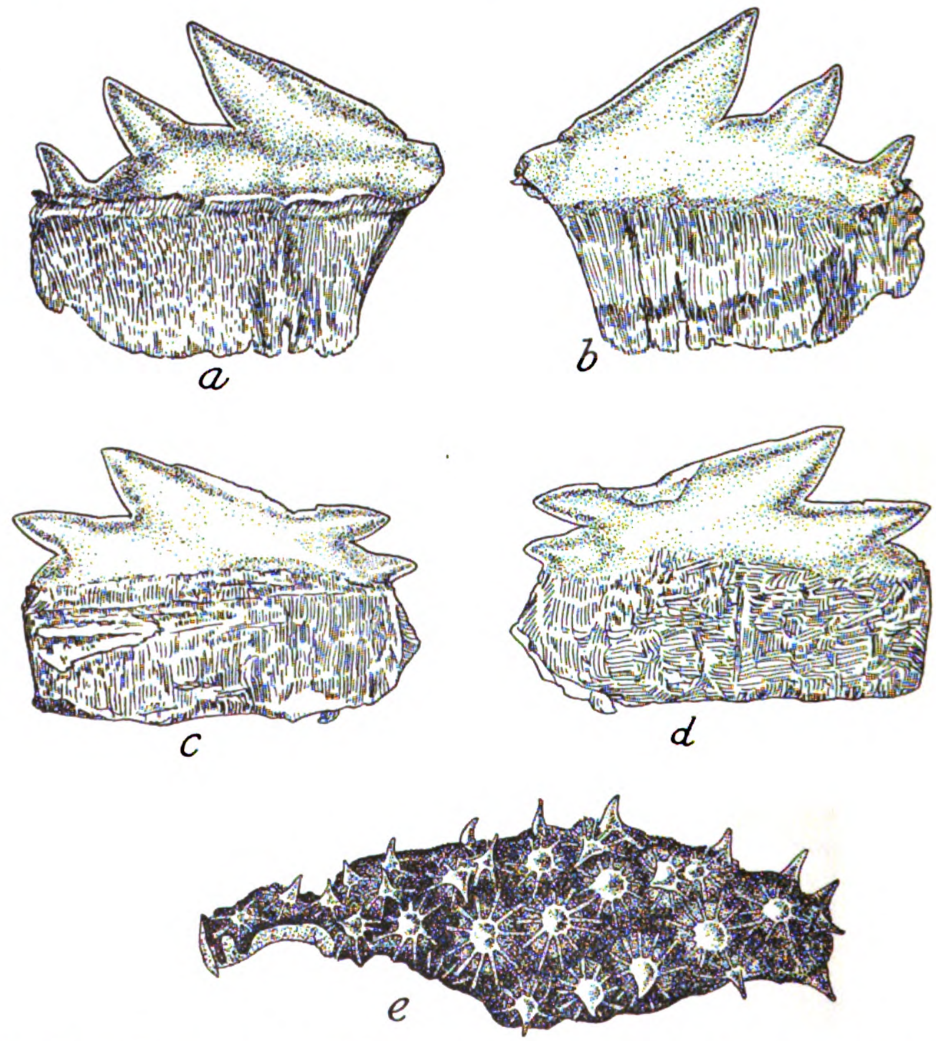

FIGURE 1.—Teeth and skin of *Echinorhinus cookei,* new species: *a,* inside; *b,* outside of upper tooth, right jaw; *c,* outside; *d,* inside of lower tooth, left jaw; *e,* skin from upper part of body, much enlarged.

of teeth in each jaw, similar, each tooth with oblique point toward angle of mouth and one to three smaller notches below point and one on inner border (toward middle of mouth). No crenulations on borders of teeth. Middle part of jaws badly preserved, impossible to determine whether any middle teeth, apparently only upper jaw has one middle tooth. Short fold around angle of mouth extending slightly on upper jaw beyond angle of mouth toward middle line. On lower jaw it reaches almost to end of outer fourth of jaw.

Nostrils about halfway between tip of snout and angle of mouth, broad with broad-based anterior flap, slightly fringed border and tip on its outer half. Posterior flap

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narrow. Eyes rather large, front half before middle of mouth. Gill openings long, last two close together.

In skin are imbedded numerous small radiating scales, disconnected, making for roughness over entire body, except on lower part of snout and immediately around mouth, which parts are nearly smooth. Light-colored lateral line running over upper half of body toward caudal fin. Pectorals broad, roundly truncated behind, with nearly straight upper border. Ventrals, with almost straight border, are large and thick on base, which begins about midway between tip of pectoral and root of caudal. Ventrals with almost straight border, slightly rounded edges. Dorsals closely set, very near caudal, which is broad with only indistinctly separated lower flap. Claspers slender, extending slightly beyond rear tip of ventral fin, fully developed. Color dark coffee-brown (in alcohol faded), lighter on belly. Snout and chin dirty-whitish with indistinct, small, irregularly distributed, dark specks. Numerous round scales on skin, especially around mouth, which indicates that food consists partly of cephalopods (*Octopus*, etc.). A half-digested carangoid, *Trachurops crumenophthalmus* (Bloch) or *Carangus affinis* (Rüppell), came from mouth after specimen placed in alcohol.

South coast of Kauai, caught on board sampan, in deep water. Bought at Honolulu Fish Market, where fishermen claim never before to have seen such a shark.

I name this very interesting species after Dr. C. Montague Cooke, Jr., the distinguished conchologist of Bernice P. Bishop Museum, in appreciation of his helpful interest in my work.

Anguilla australis Richardson.

One typical specimen, about 656 mm. long (measured with difficulty because preserved in twisted position). Pectorals and anal with very narrow milk-white border (in alcohol), color repeated on lower edge of caudal in narrow band.

Malailoa, Tutuila, Samoa, in fresh water, September, 1927, P. H. Buck.

Leptocephalus marginatus Valenciennes.

One specimen, 546 mm. long. Coloration and relative measurements of body agree exactly with Günther's description (Cat. fishes in British Mus., vol. 8, p. 38, London, 1870).

Near Pearl and Hermes Reef, April, 1927.

Ophichthys (Callechelys) punctulatus (Kaup) (fig. 2).

Sphagebranchus polyophthalmus Bleeker: Nat. Tijdschr. Ned. Ind., p. 211, vol. 16, 1858-1859.

Two specimens, 194 mm. and 218 mm. long. Head 8.1 and 8.4, distance of vent from tip of snout 2.1 in total, therefore tail shorter than body. Distance of tip of snout from beginning of dorsal 6.6 and 6.2 in total length, length of snout 6 and 5.5 in head, distance of tip of snout from angle of mouth 2.4 and 2.6, distance of tip of snout from front edge of light crossband 2 and 1.9 in head. Coloring characteristic, in alcohol upper half dark pigeon-gray to brownish, belly and lower half white, under part of head darker than lower part of body, but not so dark as upper part of head. At edge of dark color is very regular row of tiny light spots closely spaced, above which is another row of spots, larger and farther apart, the one specimen containing 19 the other 17 of the larger spots. For every 2 of the larger spots are usually placed 4 or 5 of the smaller spots in

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the lower row, rarely 3 or 6. In larger specimen, several spots on head are less distinct than those on smaller specimen, from which figures are made. The three spots in front of crossband are equally distinct on both specimens.

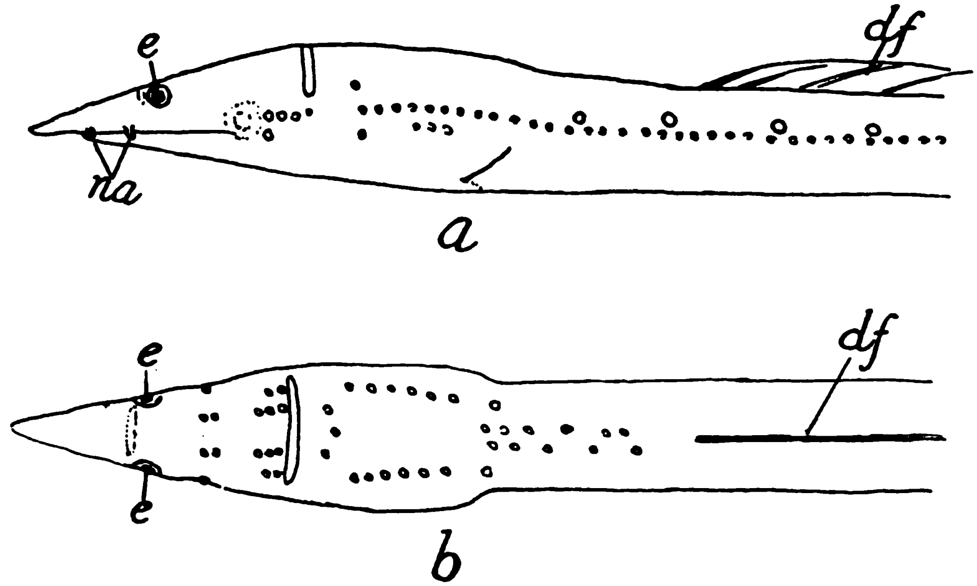

FIGURE 2.—Head and anterior part of body of *Ophichthys* (*Callechelys*) *punctulatus* (Kaup), showing distribution of light dots and streaks: *a*, side view; *b*, top view; *na*, narines; *e*, eyes; *df*, dorsal fin.

Both specimens offshore in shallow water from Hitiaa District, Tahiti, Society Islands. Collected by G. P. Wilder, who remarks that species burrows in sand, tail first.

Gymnothorax steindachneri Jordan and Evermann.

One specimen, 388 mm. long. Agrees in coloring with Steindachner's figure of *Muraena flavomarginata var.*

Pearl and Hermes Reef, T. T. Dranga.

In Bishop Museum are two casts of this species under the name *Gymnothorax kidako*, one of which is remarkable in having the black spots around the gill opening and on angle of mouth only slightly developed, also in that the black longitudinal lines on the throat, which are characteristic of both species, are very narrow and indistinct, resembling Schlegel's figure (Fauna Japonica, pl. 119, 1833). Jordan and Evermann call attention to the close resemblance of the two species. It is my opinion also that a closer relationship might well be admitted, and that all these specimens represent only color variations from one species of wide range in coloring.

Muraena kailuae Jordan and Evermann.

One specimen, 485 mm. long, richly and distinctly colored. About 20 dark crossbars with blurred borders, the first and last of which are least distinct, and indistinctly joined

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with next crossbar. The spots, white in alcohol, are more numerous than in the figure of this variable species given by Jordan and Evermann (U. S. Fish. Comm., Bull., 1903, vol. 23, p. 89, fig. 21, 1905). In this respect the specimen corresponds more closely with figure of same species on plate (op. cit., pl. 9).

Ewa, south coast of Oahu, 1928, T. T. Dranga.

Cypselurus gregoryi, new species (Pl. II, *A*).

One specimen, badly preserved, total length 382 mm., body 286 mm., head 5.5 in total, 4.2 in body. Greatest height of body 5.4 in body. D. 13, A. 9, P. I 14, about 62 scales in lateral line. Shape of body peculiar to genus, long, depressed, broad back, which narrows toward belly. Greatest breadth of body distinctly smaller than greatest height (1:1.3). Interorbital slightly concave, its breadth slightly greater than diameter of eye, which equals length of snout, or 1.2, the distance of the back eye-border from back opercular border; and 3.2, the length of head. The lower jaw overlaps slightly the upper jaw. In the lower jaw only is a single row of minute pointed teeth. Total length of pectoral 1.3 in body, overlapping caudal to almost end of scales, far beyond dorsal. The distance between the anterior end of dorsal base and root of caudal a little greater than length of head (1.1) and 1.4 in distance between anterior of anal base and the root of caudal. Height of root of caudal 1.3 in head, greatest dorsal ray slightly longer than half head (1.9). Ventral extends as far as last dorsal ray but one, length 2.3 in pectoral and one-third longer than head, starting midway between rear border of eye and base of caudal. In front of dorsal are about 35 rows of scales.

Color in alcohol dark reddish-brown with bluish metallic gloss on back and upper part of body. Straight iridescent bluish band from root of pectoral backward to center of caudal peduncle, becoming less distinct toward rear. Space beneath band pure-white. Forehead and upper part of snout same color as back. Dark bluish stripe runs horizontally slightly above middle of eye to snout. Cheeks and lower parts of head white with silvery gloss. Upper part of pectoral apparently brownish in life, becoming lighter toward rear; has near its base blurred, whitish, nearly round spot. Under side of rays silvery, without points or spots. Axle of pectoral dark, almost black. Dorsal appears uniformly light, also the anal and ventral. Ventral has deep-black spot on inner side of axle, less distinct on upper two rays. Caudal dark-brown, except rays on borders, which are whitish. Specimen, judging from scales, 13 or 14 years old.

Pearl and Hermes Reef.

This species is closely related to *Cypselurus atristrigis* Jenkins, from which it differs decidedly in the longer pectoral and longer ventral and in the difference in coloring. A very large number of species have been described in the last twenty or thirty years from the family Exocoetidae, this I believe is due to the fact that only one or a few specimens have been used for each determination, and those from widely distributed localities; whereas had ample material been available for examination, it doubtless would have been found that each true species has wider variation in coloring and form than is now believed. This is made probable by the wide distribution of the species of this family and their easy method of locomotion.

I have named this species for Professor Herbert E. Gregory, who maintained an unfailing interest in my work in the Pacific.

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Ptenonotus melanogeneion, new species (Pl. II, *B*).

One specimen, 153 mm. long. Height of head 4.4, caudal 4.5, height of body 4.8, distance from tip of snout to beginning of dorsal base 1.5, to beginning of anal base 1.8, of dorsal 2.6, of anal 4.8 in body. Diameter of eye 3.2, interorbital (above middle of eye) 4, length of snout (from tip of lower jaw) 4.8 in head. In lateral line 44 scales. D 12, A 13, P 12, V 6.

Almost directly behind the 38th scale, the lateral line becomes quite indistinct. Scales thin, deciduous, cover also basal third of caudal.

Shape of head and body corresponds to genus; strongly compressed, becoming narrower toward belly. Lower jaw distinctly overlapping upper, both without teeth. Large rectangular patch of very minute teeth on vomer, broad band of same teeth on palatines. Mouth much protracted. On chin, immediately behind middle of lower jaw, two barbels, close together at base. In basal half barbels are thin and broad, bandlike, gradually decreasing in width a little short of center, last third filiform; tip enlarged to thin flap reaching a little short of front border of eye. Eyes larger than snout, interorbital broad, flat, covered with large scales. Opercle and preopercle with smooth borders. Pectoral strongly falcated, first ray simple, others divided. The second, the longest, reaching distinctly behind end of ventral about to fifth anal ray. Ventral inserted just before end of second third of pectoral, first and second ray about half length of third, which is the longest and reaches to second anal ray. Dorsal strongly elongate with straight upper, deeply notched rear and slightly curved inner border. Notch of rear border formed by two last rays. First, second, and third rays simple, much shorter than fourth, which is longest and reaches almost to middle of upper border of caudal. Anal begins below base of dorsal. It is comparatively short, with nearly straight borders. Lower lobe of caudal twice the length of upper.

Color (in alcohol) silvery with light bluish sheen toward belly, becoming whitish. Upper third of body and neck and forehead chestnut-brown, darker on top. The two barbels deep brownish-black. Base of dorsal white, protruded portion blackish, tip deep-black. Also last quarter of ventrals black. Base of anal white, remainder of fin blackish-brown. Pectoral and caudal light.

Kona, Hawaii, 1927, T. T. Dranga.

The species *Ptenonotus melanogeneion* differs from *Ptenonotus cirriger* (Peters) in the comparatively higher body, the form and color of barbels, and the length and shape of fins, especially dorsal and ventral. Unfortunately, in the preliminary note (Anzeiger Akad. Wissensch, Wien, 13, Dez., 1928), the measurements for length of head and diameter of eye are not interchanged.

Ichthyocampus edmondsoni, new species (fig. 3).

One specimen, about 95 mm. total length, D. 20, rings 14+38, P. 10, C. 6. Height of body about equals breadth. Body angular, heptagonal, merging into four less prominent edges at abdomen, length of body 2.2 length of snout to vent. Eye moderately large, its diameter 2.3 in length of snout, exactly 6 in length of head. Operculum roundish, convex and has on base only short onset of a middle keel; dorsal keel sharp and distinct, running obliquely upward and backward. Surface roughened by roundish protuberances, neither banded nor radiating. Only six rays can be counted on a very small caudal. Color in alcohol brown. Thirteen distinct white crossbands with notched edges over back and sides, each edge bordered with dark-brown bars one and one-half to two times size of crossbands. In interspaces between these dark crossbars is an indistinct light cross stripe (12 in all). Middle three white crossbars, with bordering bars extending part way onto belly, which is white. First brown crossband lies behind head, least distinct, with only narrow border on each side.

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Waikiki Reef, Honolulu, 1927, C. H. Edmondson.

The species is distinguished from any hitherto described, principally by its striking coloring, also by the number of pectoral rays and by its rings. I

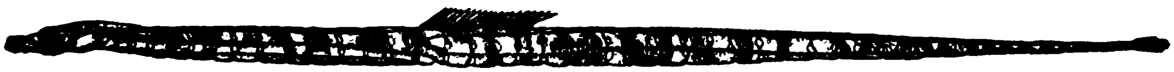

FIGURE 3.—*Ichthyocampus edmondsoni,* new species. (Drawn from the type specimen.)

name the species for the Zoologist at Bernice P. Bishop Museum and Director of the Marine Biological Laboratory of the University of Hawaii, Dr. C. H. Edmondson, who has been very helpful to me in my work.

Microphis brachyurus (Bleeker).

Three specimens, 92 mm., 98 mm., and 115 mm. long. All have a high number of rings, the largest specimen 22+25—one caudal ring more than reported by Weber and Beaufort as highest number for this species. In each specimen the number of subdorsal rings is 1 + 8. Length of snout in head 1.6, postorbicular part of head 2 to 2.4 in length of snout, length of caudal 3 to 3.8 in head, in smallest specimen slightly longer than postorbital length of head. Tail (exclusive of caudal) 1.6 to 1.7 in length of trunk. Color differs somewhat from description of Weber and Beaufort. A narrow, white border around each nostril is remarkable. White spots on snout agree with description of Weber and Beaufort (The fishes of Indo-Australian Archipelago, vol. 4, pp. 43, 44, fig. 21, Leiden, 1922). Largest specimen has small but distinct, yellowish-white dots on border of each ring, one row immediately above ventral crista. The first two rows are visible also above and below inferior crista of tail. In two smallest specimens are several blurred, light rings, the first crossing behind base of dorsal, the second about middle between this and root of caudal, the third slightly in front of caudal. On sides of body are two similar whitish spots, one approximately below middle of dorsal, the other in front of dorsal.

Papara District, Tahiti, Society Islands, G. P. Wilder. In fresh water stream, but reported by Wilder also in salt water.

Weber and Beaufort (op. cit.) state that the number of rings on this widely distributed species differs largely. The number on these three specimens is almost the same. I believe that it may be possible to trace through a statistical study of rings on a large number of specimens from various localities several local races, as was done for European Syngnathidae.

Naucrates ductor (Linné).

One specimen, 343 mm. in total length, 264 mm. length of body. D. XI, I/27, anal I, I 16. Color of caudal remarkable, both outer tips clear-white, sharply contrasted with dark color of remainder, which is almost black, intensified at end of fin. Near base of forepart of dorsal are whitish spots, in addition are sharply contoured white spots along rays of second half of fin. On border a hardly visible lighter longitudinal band.

Pearl and Hermes Reef, T. T. Dranga.

Decapterus sanctae helenae (Cuvier and Valenciennes).

One specimen, 184 mm. long. Midway on body faint traces of yellowish metallic gloss.

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Guam, 1926, H. G. Hornbostel.

Jordan and Evermann (U. S. Fish., Comm., Bull. 1903, vol. 23, p. 186, 1905) list as two distinct species *D. sanctae helenae* (Cuvier and Valenciennes) and *D. pinnulatus* (Eydoux and Souleyet), the determining factor being coloration. I believe that this separation is needless, inasmuch as the coloring is not of sufficient importance to justify it, particularly in view of the fact that the colors in either species are not constant. I agree therefore with Fowler's opinion (B. P. Bishop Mus., Bull. 26, p. 15, 1925) and that of Steindachner and Günther. Living on the surface of the water and being excellent swimmers, this species is consequently of wide distribution, but it is possible that several local varieties may be found through the examination of ample specimens from different localities. Jordan and Evermann (loc. cit.) show under plate 30 the legend "Decapterus sanctae-helenae (Cuvier and Valenciennes). Type of D. Canonoides Jenkins." In the text it is noted as the figure for *Decapterus pinnulatus* (Eydoux and Souleyet).

The relative length of the pectoral fin in Jordan and Evermann's plate 30 differs greatly from that of a specimen, 490 mm. long, exhibited as a cast in Bishop Museum. On the other hand, the pectoral length of this Guam specimen is about the same as that shown in Jordan and Evermann's plate 30. These variations, therefore, may be due only to differences in age of the specimens (in the larger specimens the pectoral length is relatively longer than in younger ones) and do not justify a division into two distinct species. Similar variation in pectoral length, according to age, is noticeable in other specimens in the Museum's collections. Jordan and Seale ([U. S.] Bur. Fish., Bull., 1905, vol. 25, p. 229, 1906) describe a new species of *Decapterus* under the name *D. lundini*. The figure to which the text refers (op. cit., p. 230) represents another fish; for the figure has no separated dorsal and anal finlets, and the soft dorsal and anal are uninterrupted. Evidently the figure represents a species of *Trachurops,* closely related to *Trachurops crumenophthalma* (Bloch).

Carangoides gymnostethoides Bleeker.

One specimen, 233 mm. long. Dorsal VI, I/35, and II, I/29, head 4.7 in total, 3.5 in body, greatest height 3.7 in total, 2.7 in body, equals length of caudal. Ventral 2 in head, 2.7 in pectoral, 2.5 in distance from tip of snout. Coloration in alcohol above a metal-like light-blue with purplish lights, on sides uniformly silvery. Without spots.

Pearl and Hermes Reef, T. T. Dranga.

Amia (Foa) fo Jordan and Evermann.

One young typical specimen. Total length 25 mm. In the caudal fin are 6+17+4 rays visible; in anal fin II/9. Lateral line extends over first 8 rows of scales, behind which are 14 additional scales. Length of caudal 2.7, height of body immediately in front of first dorsal 2.3, length of head 2.2 in body. Snout 5.5, diameter of eye and breadth of interorbital 4.1, length of pectoral 1.7, longest anal ray, which is equal to longest ray in

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second dorsal, 2, caudal 1.2 in head. Coloring almost identical with description and figure of Jordan and Seale ([U. S.] Bur. Fish., Bull., 1905, vol. 25, p. 248, 1906). Black patch on border of first dorsal very distinct and extends in this specimen to almost half across fin. Second dorsal, anal, and caudal white.

The relative variation of the dimensions between this specimen and those described by Jordan and Seale may be explained by the difference in age. The species *Foa vaiulae,* described by Jordan and Seale also from Samoa (op. cit., p. 249, fig. 43) from one specimen, I believe to be a faintly colored individual of the species *Amia fo.* My reasons for stating this opinion are: that the dark color on the neck and snout has, according to the author's figure, the same position and dimension as the specimen I have examined, and has the dark spot on the gill cover; also the black spots on border of first dorsal are similar to those in *Amia fo,* although they have not the same relative dimensions, which is to be expected in a less highly colored individual. Indistinct bars on caudal are similar in both. The former genus, *Apogon* (now *Amia*), was divided by Jordan and several other authors into several genera, based upon most minute differences. I do not believe that this classification is justified by facts, since the variations—especially differences in the lateral line, which appear on some species as a mere interruption, on others appearing only on the front part of the body—would seem to call for classification as subgenera only. Moreover, many specimens show a tendency to overlap in this feature. The descriptions and the figures of Jordan and Evermann listing several species of *Amia* (U. S. Fish Comm., Bull., 1903, vol. 23, 1905) do not correspond in the number of fin rays in dorsal and anal. On page 210 the authors describe *Mionorus waikiki* [sic.] "D 8 soft rays, A 7." Plate 35 shows in each dorsal and anal 9 soft rays. On page 211, they note for *Foa brachygramma* (Jenkins) "A. 8 soft rays"; the figure shows 7. On page 214, for *Amia snyderi* (Jordan and Evermann) "D. 9 soft rays"; while the figure shows 10, plate 36 shows 8.

East shore of Kaneohe Bay, Oahu, on an iron wreck in shallow water, covered with algae and Bryozoa. V. Pietschmann. Previously known only from Apia, Samoa.

Amia novemfasciata (Cuvier and Valenciennes) (fig. 4).

Apogon aroubiensis Hombron and Jacquinot: Voyage au Pole Sud, Poiss., p. 31, pl. 1, fig. 1.

Amia exostigma Jordan and Starks; Jordan and Seale: [U. S.] Bur. Fish., Bull., 1905, vol. 25, p. 238, fig. 31, 1906.

Eleven specimens 21 mm. to 70 mm. long. Length of caudal 4± (3.8 to 4.4) in total, 1 to 1.3 in head; head 2.2 to 2.8 in body, greatest height of body, slightly before beginning of first dorsal, equal length of head or slightly smaller (1 to 1.4, most specimens 1.1 to 1.2); greatest height of body 2.3 to 3.5 in length of body. Relative height of body increases in older specimens, so that larger specimens are distinctly higher than young ones. Snout[1] 4 to 4.7, diameter of eye 2.7 to 3, interorbital (in 3 specimens) 4 to 4.3 in

[1] This and the following measurements are taken from only 6 specimens.

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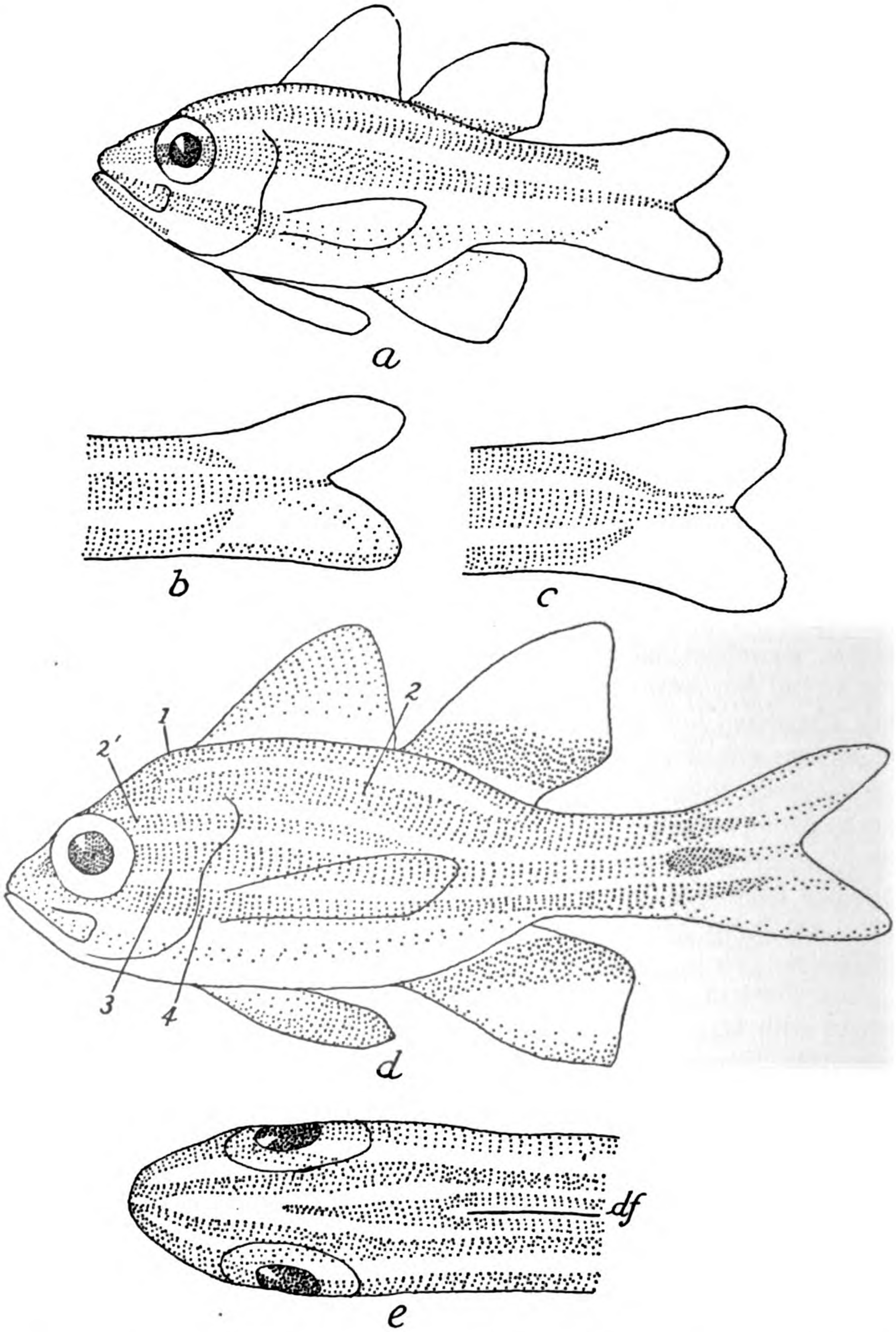

FIGURE 4.—*Amia novemfasciata* (Cuvier and Valenciennes), showing variation in color arrangement: *a-d*, side views; *e*, top view; *df*, dorsal fin; 1, 2, 2′, 3, 4, color bands. Length of *a*, 21 mm.; of *b*, 70 mm.

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head. Length of pectoral distinctly smaller than length of head (1.3 to 1.9), most specimens 1.5. Length of base of anal (in 5 specimens) 2.5 to 2.7 in head.

Coloring greatly variable. In brighter specimens black bands are narrower than interspaces, also less distinct. In dark-colored specimens bands are sharply defined. In one specimen on front part of body is an additional band between second and third longitudinal bands (fig. 4, *d*, 2), all bands are more deeply black, longer, and broader: three center bands continued on caudal, forming black seams, and upper and lower border of caudal edged with dark. In most specimens the two lowest bands are less distinct and not so dark as the upper bands; especially the fifth band is in several specimens visible only on chin, forming there a short, narrow dark stroke. On the single specimen (fig. 4, *d*) the middle band is also intensive on root of caudal, so that it forms an oblong, dark spot. In coloring of fins are remarkable differences: in dark-colored specimen (fig. 4, *d*) more than upper half of first ventral dark, resembling specimen figured by Jordan and Seale (op. cit., p. 243, fig. 36), as does also dorsal. The band-like dark color on base of second dorsal and anal in all specimens varies from broad, distinct bands separated by light, narrow, basal seam from dark color of back to an extremely narrow, dark line —in some disappearing entirely. Very remarkable differences exist in the extension and intensiveness of longitudinal bands on root of caudal and on caudal (fig. 4, *a-d*), which complement figures of Jordan and Seale (op. cit., pp. 242, 243, figs. 35, 36, 37). In figure 4, *d*, all five bands extend onto caudal, forming blackish, more or less distinct stripes; in other specimens only middle band extends to border of middle of caudal, whereas 2 and 4 convene, forming arch on root of caudal. Intermediate between these is a specimen (fig. 4, *c*) in which band no. 2 is continued to near border of caudal, forming fine stripe. In specimen showing least coloration, band no. 4 is almost invisible on caudal root. On cheeks and part of body which lies before pectoral, between bands no. 3 and no. 4 and between nos. 4 and 5 are interspaces which show in alcohol intensive mother-of-pearl sheen, gradually disappearing toward rear. In several specimens interspace between bands nos. 3 and 4 is restricted on snout to a very narrow but distinct white line, extending from tip of snout to eye. Coloring of head and front part of body seen from above very characteristic. (See fig. 4, *e*.)

Suva, Fiji, shallow shore water, in coral blocks near Fiji Museum, 1926, H. S. Ladd.

In consideration of these many variations in coloring, I believe that a division of *Amia aroubiensis* and *Amia novemfasciata* into two species is an error. This separation is chiefly based on differences in coloring of root of caudal, which is not sufficiently constant for such determination. In the same manner, I believe also that *Amia exostigma* Jordan and Starks, which is described and figured from 8 specimens from Apia and Pago Pago, belongs to *Amia novemfasciata,* being only slightly and indistinctly colored specimens. This is proved by the identical position in both species of basal bands on second dorsal and anal, and the position of a longitudinal band, which is identical with the position of the middle band of *Amia novemfasciata,* even to the spot on root of caudal, corresponding to spot shown in figure 4, *d*. The largest specimen has an interesting abnormality of spines in the first dorsal (Pietschmann, Eine merkwürdige Flossenabnormalität bei Amia novemfasciata: Zool. Anz., vol. 84, p. 91, 1929).

Hynnodus (Scepterias) fragilis (Jordan and Jordan).

One specimen, 127 mm. long. Head 2.7, greatest height of body 4.6, length of caudal 4.1, distance from tip of snout to base of first dorsal 2.4, to beginning of second dorsal

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base 1.6, to beginning of anal base 1.5 in body. Diameter of eye (horizontal) 2.2, length of snout 4, caudal 3.5 in head, breadth of interorbital 1.8 in eye. D VII, I/9, A II/9, scales in lateral line about 51.

Nearly all scales of body lost, only those in lateral line partly preserved. Second dorsal commences a little in front of pectorals, below end of first dorsal; end of ventral a little to rear of center of pectoral.

Honolulu, March 15, 1896, collected by the Austrian cruiser *Donau*. Not well preserved.

This specimen differs somewhat from the description of Jordan and Jordan, particularly in the formula of second dorsal, to which Jordan attributes 10 soft rays. Also they differ in the number of scales in the lateral line, the specimen I examined having 51, instead of the 54 mentioned by Jordan. The body of this specimen is relatively shorter than that described by Jordan. These differences are not sufficiently important to deserve naming a new species, but may be attributed to differences in growth.

Likewise I believe that the separation of this species from the genus *Hynnodus* into a new genus, *Scepterias,* is not justified, but that at most a subgenus is sufficient for these differences. According to the picture of *Hynnodus atherinoides* Gilbert (U. S. Fish Comm., Bull., 1903, vol. 23, pl. 79, p. 618, 1905), the specimen seems to be a young fish of a large species. This opinion is based upon the manner of pigmentation, which has a typical larval appearance. Perhaps, therefore, the specimen is also more slender.

Grammistes sexlineatus (Thunberg).

One specimen 65 mm. long. Two broad lateral stripes, milky-white in alcohol, one from upper border of eye, one from lower edge of eye beneath angle of operculum along body; on caudal peduncle both stripes sharply converge, diminishing in size. In addition are two narrow fine lines, same color, one above broad stripes beginning halfway between eye and base of pectoral, extending to below middle of soft dorsal; the other line below broad stripes, beginning on border of opercle, extending to end of anal. End of maxillary white, white spot on edge of mouth. Oblique milky-white line on back border of operculum, smaller line beneath the first on branchiae. On middle of back longitudinal stripe from snout to beginning of first dorsal, continuing as fine line on front border of dorsal, only slightly narrower than two principal stripes. Small longitudinal stripe along middle of belly, from throat to vent, on base of ventral enlarged to broad spot. All stripes milky-white in alcohol.

Suva, Fiji, 1926, H. S. Ladd.

Upeneus multifasciatus (Quoy and Gaimard).

Two specimens, 211 mm. and 249 mm. long. Length of head 2.9 and 3, height of body 3.4 and 3.5 in body, diameter of eye 5.8 and 6.3 in head, 3.3 and 3.4 in snout. Interorbital breadth distinctly greater than diameter of eye (1:1.5) and contained 2.3 times in length of snout. Barbels reach in both specimens only a little behind edge of ventral. In lateral line I counted 31 scales, 2 of which are on caudal base. In both specimens characteristic, slightly slanting, white bordered, dark snout band plainly visible, and extends from front part of mouth to eye. Breadth equal to diameter of eye. About six dark, indistinctly bordered crossbars on body are hardly visible in alcohol—one be-

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fore first dorsal, the second, very broad, beneath dorsal, the third between first and second dorsal, two below second dorsal, and one on caudal peduncle and caudal base.

Guam.

Fowler notes relative length of head and height of body (B. P. Bishop Mus., Bull. 38, p. 16, 1927) in a specimen 51 mm. long 1 1/5, for the relation from eye to head 3 1/3. In young stages evidently eyes are relatively much greater than in old ones, as is true in most species of fishes. For instance, *Sciaena aquila* (Pietschmann, Ann. Nat. Hofmus, Wien, vol. 21, p. 103, 1906). This is a new proof that the dimensions of the eyes have only a slight value for determination of species, because of their great variability.

Oxycirrhites (Cirrhitoidea) bimacula (Jenkins).

One specimen, 40 mm. long. In lateral line 43 scales, in transversal line 4, 9. Each dark crossbar and both black spots surrounded by a small white line (in life perhaps light-blue), ground color of body in alcohol light-brown.

It would seem that the difference between this species and *O. typus* Bleeker, as noted by Jenkins (U. S. Fish Comm., Bull., 1902, vol. 22, p. 489, 1904)—consisting principally in the length of snout—while very remarkable, is not of sufficient importance to justify making a new genus. I believe that the true relation would be shown were the species of Jenkins consigned to a subgenus of *Oxycirrhites*.

Pearl and Hermes Reef, T. T. Dranga.

Cirrhitus marmoratus (Lacèpede).

One specimen, 205 mm. long. Snout 3.2, interorbital 6, length of maxillary 2.3 in head. In other characters the specimen agrees with description by Jordan and Evermann (U. S. Fish. Comm., Bull., 1903, vol. 23, p. 452, 1905), with the addition of rusty-brown spots (in alcohol) on dark bands of body, spinous dorsal at base of soft dorsal and on anal fin. Light portion of body—especially gills, throat, and belly—seems to have been in life, rose-colored.

Pearl and Hermes Reef, April, 1927, T. T. Dranga.

Paracirrhites cinctus (Günther).

One specimen, total length 99 mm. Differs from description of Jordan and Evermann (U. S. Fish. Comm., Bull., 1903, vol. 23, p. 449, pl. 68, 1905) in having 51 perforated scales in the lateral line, behind which are 3 or 4 more rows on base of caudal. Length of head 2.9, greatest height of body 2.6, height of caudal peduncle 7.9 in length of body. Ground color in alcohol, orange with rosy glow on body, rose shade becoming more pronounced on sides and belly. Head and throat more brownish above. Snout, forehead, and neck to edge of dorsal covered with small, brown, ill-defined dots, which also border scales. On operculum in front of rear angle is distinct brownish-black spot having a faded appearance at rim, several smaller indistinct spots and streaks similar in color on cheeks and throat. On body are 5 blood-red crossbars, the first reaching to third dorsal spine, second starting behind the fourth spine and ending beneath the seventh, the third beginning below the eighth and extending to below the third soft ray, the fourth beginning beneath the fifth soft ray and continuing to the ninth ray, the fifth starting

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under the last ray but one and occupying entire front half of caudal peduncle and having an indistinct brownish spot in the center. The rear of ventral, all of the soft anal, and lower part of caudal dark; pectoral shows but little brown.

Fish Market, Honolulu.

The position of the crossbars agrees so closely with the description of Jordan and Evermann that there is no doubt that the specimen belongs to this species, even though some of the coloring differs.

Microcanthus strigatus (Cuvier and Valenciennes).

Five specimens, 116 mm. to 142 mm. in total length. All have below the six longitudinal bands described by Jordan and Evermann (U. S. Fish Com., Bull., 1903, vol. 23, p. 376, 1905) a seventh one less distinct but clearly visible. This branches from the sixth, immediately in front of axle of pectoral, extending parallel with it below base of pectoral, where in some specimens it is only finely traced, to above center or end of base of ventral.

Honolulu Fish Market, 1928, Victor Pietschmann.

Heniochus acuminatus (Linné) (Pl. III, *A*, *B*).

One specimen, 71 mm. long. Height of body immediately in front of longest dorsal 1.4, head 2.6, length of caudal 4 in length of body, length of pectoral exactly equals length of head and is only slightly shorter than ventral, snout 2.6, diameter of eye 2.9 in head, dorsal (XI/27). In lateral line 58± rows of scales, those on caudal peduncle considerably smaller than others.

Suva, Fiji, 1926, H. S. Ladd. Caught under old coral blocks in flat shore-water in front of Fiji Museum.

The specimen differs in several characteristics from the illustration of this species by Jordan and Evermann (U. S. Fish Comm., Bull., 1903, vol. 23, pl. 55, 1905): the dark color on the snout reaches only slightly in front of the eye; the deep-black band between the eyes is continued across the eyes; between this and the first broad, black crossband of the body lies a small black spot on the back; the first and second black crossband of the body are both bent to the rear on the dorsal fin; the third crossbar, as shown by Jordan and Evermann (loc. cit.), being slightly lighter than the first two, is lacking altogether in the specimen here described, which in other respects is much darker.

Heniochus chrysostomus (Cuvier and Valenciennes) (Pl. IV).

One specimen, 89 mm. long. Height of body 1.5, length of head 2.7, length of caudal fin 3.9 in length of body, snout 2.9, diameter of eye 3.2, interorbital 3.8 in head, length of ventral slightly smaller than length of head, length of pectoral distinctly greater (1.1). Black oval spot with small white border on second half of anal within second dark crossbar of body very distinct, also longest dorsal and following spine, as well as ventral, strikingly darker than other bar.

Guam, H. G. Hornbostel.

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This species is distinguished from *H. acuminatus* (Linné) not only by minor differences in proportions of the body, but especially in coloration, differences that appear also on the top of the head. *H. chrysostomus* has no dark crossbar between the eyes, but the upper part of snout and neck are light, except for a black longitudinal line passing along the middle of the head, starting at tip of snout and extending to the end of the first half of the interorbital. This line gradually becomes less distinct toward the rear. The first dark crossbar borders the eye, which is uniformly colored without a dark vertical bar like that in *H. acuminatus*. The forehead is almost smooth in the specimen here described (without front tubercle).

Scorpaenopsis gibbosa (Bloch and Schneider).

Two specimens, 86 mm. and 100 mm. long. Height of body 2.4 and 2.6 in body; diameter of eye 5.5 and 5.7, length of snout 3, breadth of interorbital 4.4 and 4.5 in head. I counted 47 longitudinal rows of scales in larger specimen extending to root of caudal, in caudal peduncle about 3 additional smaller ones; in the smaller specimen are only 46 rows in all. In both specimens broad, dark-brown stripe distinctly visible, rear border sharply defined, front border fading gradually toward front, back border extending from base of seventh dorsal spine obliquely downward to slightly behind upper axle of pectoral. In larger specimen this stripe has on both sides a whitish ring, which is dense beneath second to fourth dorsal spines. In both specimens ventral deep-black, becoming lighter toward base, in larger specimen having on it an indistinct lighter spot. Edge of ventral in both specimens bordered with broad white band. Similar coloring, black with broad, white edge, also on caudal. In front of base of caudal extending over belly is short white crossbar, in front of which is brownish crossbar becoming faded toward front. Marbling of body beneath soft dorsal indistinct. In smaller specimen bars on caudal are very dark brown and sharply defined. On pectoral, 7 longish black spots between rays, on larger specimen very distinct, on smaller specimen all but first ones faint.

Waikiki Reef, Oahu, 1927, Victor Pietschmann.

The number of scales seems quite variable in this species, also the coloring. The marbling is less distinct than shown by Jordan and Evermann (U. S. Fish. Comm., Bull., 1903, vol. 23, p. 469, fig. 206, 1905), but lies on the same part of the body. Also the interorbital space in both specimens is slightly narrower than in the animal described by Jordan and Evermann.

Sebastapistes coniorta (Jenkins).

Seven specimens, 33 to 68 mm. long. The number of the lateral rows of scales ranges from 53 to 55. Slight differences appear also in coloration, but the characteristic crossbars are in each specimen distinct and appear on identical parts of the body.

Pearl and Hermes Reef, T. T. Dranga.

Pterois radiata (Solander).

One specimen, 57.5 mm. long. Length of body 41.5 mm.; length of head 3.2 in total, 2.3 in body; greatest height of body 2.7 in body, 1.2 in head; diameter of eye 3.6; interorbital space 6.7 in head, 1.8 in eye; length of snout about equal to diameter of eye, 3.5 in head; cutaneous tentacle above eye slightly longer than twice diameter of eye, base of tentacle broad, diminishing in breadth toward top. About 60 rows of scales, 26 of

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which are perforated by lateral line. Ground color of body in formalin very distinct but delicate pink to flesh color. The same coloring on snout, lower parts of cheeks, and throat. Dark brownish-black crossband noted and figured by Günther (Fische der Südsee, vol. 1, p. 8, pl. 56, fig. A, 1873-75) in this specimen distinct and in identical position but not so broad, so that interspaces very prominent; but three brown-bordered light bands figured on lower part of body in front of pectoral lacking. The dark bands continue entirely around body. Between first two bands on forehead, behind eyes, is short, dark crossband extending to middle of height of eye. Tentacle above eye black. The black color continues to border of eyeball, forming continuation of first dark crossband. Third band, which runs beneath base of first dorsal spine, also continued by oblong spot of about same breadth over middle of pectoral. Skin between rays of pectoral also black. Rays show ground color of body. Rear borders of anal, of soft dorsal, and of caudal black. Spots indistinctly visible on anal, soft dorsal, and caudal; on edge of caudal fin distinct. Said by natives to be very poisonous, according to notations of collector.

Reef in district of Papara, Tahiti, Society Islands, January, 1927, G. P. Wilder.

Dendrochirus chloreus (Jenkins).

One specimen, badly preserved. Length of body 44 mm. (Part of caudal lacking.) Deep-black spot behind upper edge of opercle, broad dark band along rear opercular border; a distinct oblique band extending from middle of second dark crossband on head toward lower part of pectoral base and lower basal part of this fin, there becoming broader and more distinct. Otherwise coloration typical.

Kaneohe Bay, May, 1928, T. T. Dranga.

Trigla kumu Lesson and Garneri.

One specimen 376 mm. in total length. On pectoral dark bluish-black spot, surrounded by distinct whitish small spots, all characteristic of this species. Longest dorsal ray longer than distance of front nostril from angle of operculum (1.1), pectoral extends only to below edge of dorsal, and is outlined by light-blue band about 5 mm. wide. Body is irregularly mottled with lighter color on upper half.

Near Napoopoo, west coast of Hawaii, October, 1922.

Heretofore this species has not been noted from Hawaii.

Thalassoma dorsale (Quoy and Gaimard).

One specimen, 186 mm. long. Coloring, which is in general typical of the species, shows the following differences: first indigo-blue crossbar extends on back from neck, overlapping beginning of spiny dorsal, in center of front half of crossbar interrupted by two light, vertical bars, reaching from light ground of belly across dark coloring, connected on lateral line by white crossband on which a part of dark crossband is isolated. This crossband, diminishing in size posteriorly, ends below the lowest pectoral rays, the following three crossbars in middle line of body; the last, indistinctly bordered, above middle line. A dark ovoid coloring appears on center of end of caudal, both lobes of caudal bordered by red streak, mentioned by Jordan and Seale ([U. S.] Bur. Fish., Bull., 1905, vol. 25, p. 307, 1906).

Guam, 1925, H. G. Hornbostel.

Thalassoma purpureum (Linné).

Thalassoma umbrostigma (Rüppell): Neue Wirbeltiere, Fische, p. 11, pl. 3, fig. 2, 1838.

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Thalassomma berendti Seale: B. P. Bishop Mus., Occ. Papers, vol. 1, no. 4, p. 15, fig. 7, 1901.
Two specimens, 173 mm. and 279 mm. long.

Pearl and Hermes Reef, T. T. Dranga.

After comparing these two specimens with many individuals in the collections of Bernice P. Bishop Museum, I believe that *T. purpureum* and *T. umbrostigma* without doubt should be united in one species, as is tentatively proposed by Günther and Klunzinger, and that they represent only variation in coloration. This opinion is upheld by the fact that the type of coloring and drawing is identical, and further that these two specimens here referred to show transitions between the two forms. The larger specimen bears the typical coloring of *T. purpureum,* but it has at the beginning of the dorsal a distinct black spot, although with blurred edges, which reaches to the third dorsal spine; in the same manner, the axle of the pectoral is distinctly black. The smaller specimen shows in coloring much more clearly the type of *T. umbrostigma,* having at the beginning of the dorsal a distinct black spot about the same size and position as that of the other specimen, the axle of pectoral also being black, but in the anal fin are 3 spines and 11 rays as in *T. purpureum.* In both specimens the length of the head is considerably less than four times the total (3.6); in the smaller one it is distinctly greater than the greatest height of body (1⅛). It may be noted that all the specimens examined in the collections of Bernice P. Bishop Museum that have been determined as *T. umbrostigma* have 3 spines in the anal fin; further, that most of the specimens of *T. purpureum* show the black spot at the beginning of the spiny dorsal, some very faintly. It is possible that these differences are due to sex. Finally, I believe, *T. berendti* also is no more than a specimen of *T. purpureum,* which differs slightly in coloration from the normal.

Scaridea aërosa Jordan and Snyder.

A specimen of this species, 266 mm. long, described by Jordan and Snyder in 1906 ([U. S.] Bur. Fish., 1905, vol. 26, p. 215, 1906), in the Vienna collection has on the lower part of the gill covers two creamy-white vertical bars, both about one-half as wide as the diameter of eye. The first, below first half of eye, beginning about halfway between angle of mouth and lower opercular border; the second, a little behind the eye, beginning on line with angle of mouth, both reaching to lower opercular border, the second slightly curved and irregularly bordered. Upper border of eye blackish-brown, skin between first and second dorsal spine black, becoming lighter toward border of fin; also base between second and third spine black, the color blending with the black between first and second spine.

Honolulu.

Callyodon bennetti (Cuvier and Valenciennes).

One typical specimen, 242 mm. long.

Honolulu Fish Market, 1928.

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As this species has a distinct posterior canine tooth, its position in the key of Jordan and Evermann for *Callyodon* (U. S. Fish Comm., Bull., 1903, vol. 23, p. 346, 1905) under the species without posterior canine tooth is an error, which is repeated in the description (op. cit., p. 352). The specimen shows three distinct white stripes on the belly, identical with the figure by Jordan and Evermann (op. cit., pl. 45), though in their description only two are recorded. The caudal fin of the specimen is slightly but distinctly luneate; their description and figure show it slightly rounded. About four indistinct traces of crossbands which appear on the upper half of body of the specimen are recorded in neither the description nor the figure of Jordan and Evermann.

Sicyopterus stimpsoni (Gill).

One specimen, 95 mm. long. Dark submarginal band on anal very distinct; upper lip and adjacent parts blackish. Body uniformly colored, without marks or spots.

Waiahole, Oahu, June 21, 1927, C. S. Judd.

Enneapterygius atriceps (Jenkins).

Three specimens, 228 mm., 235 mm., and 325 mm. long. In all specimens snout and lower part of head to throat black; black also from middle of eye to beyond upper edge of gill cover and as far as pectoral, on throat in front of ventral sharply bordered. As seen from above, light part of forehead extends with obtuse angle between eyes; beyond eyes two specimens have indistinct lighter stripe, which in one becomes broader toward belly, extending across dark color. Similar lighter crossbar in front of eyes. Intermediate specimen most brilliantly and distinctly colored, has two brownish red crossbands in front of pectoral, extending to level of lateral line, being separated by narrow, white interspaces; first crossband covering front part of gill. Six additional dark-brown crossbars, two being in front of anal: first extends beneath to belly, joined above with second, which reaches only to lateral line; between second and third bands is broken band with lighter center extending from lateral line across belly; third band broadest, with lighter center, its rear half only continued below lateral line across belly, the lower part also with lighter center; last three crossbands continued beneath lateral line across belly, where they have also lighter spots in center. Interspaces between crossbars below lateral line very light and give impression of light eye spots. Ground color of body in alcohol rose-red; on base of anal nine dark spots; first dorsal shows deep-black spot behind last spine, otherwise blackish; distinct black spots on base of second dorsal between each two spines, except last three, otherwise fins uncolored except very indistinct tiny dark dots on base of third dorsal. In largest specimen, which is longest preserved (1923), no differentiation is remarkable in coloration of fins, also bands of body in this specimen are very light. Smallest specimen corresponds in coloring with intermediate specimen, though lighter than it is in coloration, crossbars are more reddish-brown; black spot on first dorsal lacking and instead of basal spots of second dorsal has corresponding, narrow, blackish band.

Waikiki Reef, Oahu, in front of Marine Laboratory, from holes in coral blocks.

In their position the six crossbars correspond exactly in position with those figured by Jordan and Evermann (U. S. Fish Comm., Bull., 1903, vol. 23, p. 496, fig. 219, 1905). However, the description in this work disagrees

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with the figure in the dimensions of the body. When measured by me, the proportions of the illustration conform much more closely with those of the specimen here described than do those of the description. The differences are as follows:

	SPECIMENS IN BISHOP MUSEUM 1	2	3	JORDAN'S FIGURE	JORDAN'S DESCRIPTION
Head in body	3.7	4.3	4.3	3.4	3.25
Height in body	4.6	5.7	5.7	4.3	4.6
Diameter of eye in head	3.3	3.2	3.5		
Length of snout in head	4.9	4.2	4.1	4.7	3.4

Particularly the length given for the snout must be erroneous, for in all specimens examined it is smaller than the diameter of eye (also in Jordan's figure).

Salarias fasciatus (Bloch).

One specimen, 114 mm. long. Length of caudal 4.7 in total, dorsal XIV 21, anal 21, pectoral 14, C 3+13+2 or 3. Height of body in front of beginning of anal 4.2, head 4.6, length of pectoral from lower pectoral axle to rear tip of fin 4 in body, pectoral therefore slightly longer than head (1.1). Distance from beginning of dorsal to tip of snout 5.5, distance from beginning of anal to tip of snout 1.9 in body. Diameter of eye 3.7, postorbital 1.5, height of caudal peduncle 2.3, distance from beginning of dorsal to tip of snout 1.2 in head. Body high, strongly compressed, head moderately great with snout vertical in profile, above each eye thin, bifid, tiny tentacle, which is only slightly shorter than diameter of eye (1.1). On neck, shorter, undivided, unfringed tentacle, with lanceolate tip, broad side toward snout, length 1.7 in diameter of eye, inserted slightly behind middle of distance from eye tentacle to beginning of dorsal (1:1.2), front part of anal greatly elongated, its first three rays exceedingly filiform, the second the longest. Skin of fin between rays extends only slightly over first third of rays; also deeply incised between following rays. Only last rays of anal nearly entirely imbedded in skin.

On olivaceous ground color of body in alcohol, especially in its lower parts to base of anal, are indistinct, longitudinal, milky-white spots with blurred edges, becoming more distinct toward anal. Most of spots decidedly oblong, only lowest and middle rows above anal base composed of roundish spots. Belly milky-white. Head indistinctly spotted, borders of preoperculum and operculum with narrow, white edge. Tentacle of eye in its lower half light, becoming darker above. Chin and throat, except for light spot in middle, very dark, followed by two small, dark bands, one beginning at rear border of operculum and extending to base of ventral, the other also from operculum border to about middle of ventral. Dorsal dark. Slanting rows of long white spots extend obliquely upward through dorsal from base, the dark ground color of front part of dorsal composed of minute dark spots, densely placed, dark ground color of second half of fin solid. Above anal are three dark longitudinal rows; the first, immediately above base, more than twice as broad as either of others; interspaces between rows milky-white; outer part of anal becoming darker toward border, the edge being nearly black. Pectoral and ventral strikingly colored, with irregular cross rows of blackish, oblong spots. Similar cross row of dark spots extends above caudal, remainder of caudal also dark.

Suva, Fiji, in shallow water from coral blocks off shore, 1926, H. S. Ladd.

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Between descriptions formerly made and this specimen the differences are considerable; for instance, in the shape of the second tentacle and in the number of fin rays, also in the length of rays in the forepart of the anal. Were it not that the coloring of this specimen is identical with that of *Salarias fasciatus,* a new local variety, if not a new species, would be in order. It may be that the differences are due to sex, but to reach this decision investigation of a large number of specimens would be necessary.

Enchelyurus ater (Günther).

Two specimens, 30 mm. and 31 mm. long.

Kaneohe Bay, near Coconut Island, in cavities of dead coral from the reef, December, 1927, Victor Pietschmann.

Tetrodon meleagris Lacépède.

One specimen 50 mm. long, length of body 1.3, length of head (tip of snout to middle of gill slit) 2.4, distance of tip of snout from beginning of dorsal base 1.4, from anal base 1.3, distance of lower end of pectoral axle from back 3.3[2] in body. Length of snout 1.8; eye, which equals the interorbital, 3.1; breadth of pectoral base 2.8, of dorsal base (measured from first extension in contour) 2.9, of anal base 4.1 in length of head. The specimen is covered with numerous bluish-white spots, so that on greater part of body ground color appears as coarse mesh. Spots on head more or less roundish, also on caudal peduncle and behind pectoral. On remainder of body spots oblong, some of them irregular in form; those on belly beneath pectoral particularly long and narrow, forming rather regular longitudinal rows. Ring of white spots around eyes distinct as shown by Garrett and Günther (Fische der Südsee, vol. 3, pl. 174, Hamburg, 1909-10). Spots on head are in alcohol light-blue, bordered by very narrow dark-blue lines. Fins uniformly white.

Waikiki Reef.

Tetrodon immaculatus Bloch and Schneider.

Two specimens, 67 mm. and 210 mm. long. In the longer distance from top of snout to gill opening 2.3 in body, caudal length 2.6; caudal slightly longer (1.1) than distance of root of caudal from beginning of dorsal base; distance of dorsal from base of caudal 1.4 in caudal length, length of snout slightly longer than half distance of top of snout from gill opening: shows coloring of juvenile form of this species (described by Bleeker as *Crayracion manillensis*) with the exception that the olive-green stripes are much more numerous than in Bleeker's figure (Atlas ichth., vol. 5, pl. 208, fig. 2) and are also visible on the very dark back. In smaller specimen, which is very dark, dorsal has 10 and anal 11 rays; head (distance of top of snout to gill opening) 2.5; length of caudal 3.3 in body; length of snout 2.2 in head; in this specimen also caudal is slightly longer than distance of base of caudal from beginning of dorsal base (1.2); distance of dorsal from caudal base 1.8 in length of caudal.[3]

Even in view of the fact that *Tetrodon immaculatus* has a great variability, the smaller specimen at first view appears quite different from the de-

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[2] I take this distance instead of height of body because as all balloon fishes are able to extend greatly the belly it is impossible to take exact measurements of height.

[3] Colors of this specimen will be described in a paper on juvenile stages of Pacific fishes, which I hope soon to prepare.

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scriptions and also from the larger specimen, but an examination proves its identity with this species.

Suva, Fiji, 1926, H. S. Ladd.

Tetrodon nigropunctatus Bloch and Schneider.

One specimen, 186 mm. long. Length of caudal 3.4; head 2.6 in body; pectoral equals length of snout 1.9 in head; eye 6.2; head of caudal peduncle 2.8 in head; border of orbital slightly raised; caudal considerably longer (1.3) than its distance from base of dorsal. Coloring very remarkable: ground color in alcohol drab-brown, on back becoming distinctly dark, belly slightly lighter; on body roundish spots, indistinctly bordered, hardly visible; in ground color are irregularly distributed deep-black, roundish spots of various sizes, the largest about a third diameter of eye; tips of spines extruding from skin white, giving the specimen the appearance of being covered with tiny white spots; eyes surrounded by dark-brown rings indistinctly bordered; in the same manner snout and environs of pectorals dark-brown; border of mouth black, also base of pectoral and vent, which is formed like a bent furrow, immediately in front of base of anal; of equal darkness are tentacles of nostrils; silvery-white band extends horizontally over forehead, beginning at snout and ending beneath eye, its breadth slightly smaller than diameter of eye, tentacles sharply contrasted.

Guam, H. G. Hornbostel.

In coloring and dimensions this specimen differs in several characteristics from all previous descriptions. Garrett and Günther (Fische der Südsee, p. 468) notes for border of orbital "not raised," and "caudal fin and its distance from base of dorsal equal." Also in no description is mentioned the silvery-white band on the forehead. Even so, I believe that the differences listed in the above description are insufficient to create a new species. To determine whether this represents a local variety, more extensive material for comparison is necessary. If the differences in ample material are found to be constant, the determination of a new variety is justifiable.

Antennarius nummifer (Cuvier).

Antennarius drombus Jordan and Evermann: U. S. Fish. Comm., Bull., 1902, vol. 22, p. 207, 1903.

Antennarius nexilis Schneider: U. S. Fish. Comm., Bull., 1902, vol. 22, p. 537, pl. 13, fig. 23, 1904.

One specimen 61 mm. long. Brown, becoming rose-red on belly, particularly toward throat. In ground color numerous indistinct darker spots and marblings, several of which are edged with lighter. On lighter part of belly these darker spots are very distinct. Base of cuticular flaps of body characteristically colored by small, very dark, blackish-brown spots bordered by whitish lines. In same manner excretory ducts of mucous tubes in lateral line darker. On both sides of isolated third dorsal spine whitish crossbar extends vertically. About equal with diameter of eye. Beneath second half of soft dorsal, roughly below fifth to seventh dorsal, is larger, dark, light-bordered, irregular spot, its longest diameter $1\frac{1}{4}\pm$ diameter of eye. On soft dorsal 3 longitudinal rows of dark-brown dots, on anal 2. Edges of both fins white. Basal half of pectoral same color as body, rear half becoming lighter. In rear half two rows of dark-brown dots with broad, white edges extend across fin. Dark-brown dots on caudal fin arranged in five indistinct crossbands, border of caudal white.

Waikiki Reef, 1923.

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As in *Antennarius commersonii* (Lacépede), in this species the coloring and design has, I believe, an extremely great variability. To make a new species, *Antennarius drombus,* as is done by Jordan and Evermann, which by Jordan and Seale is considered doubtful ([U. S.] Bur. Fish., Bull., 1905, vol. 25, p. 438, 1906), is not justified by the facts. As to coloring, this specimen is halfway between *Antennarius drombus* and *Antennarius nexilis*. Aside from coloring there is no important difference in the two species, which are also from the same locality (Waikiki, near Honolulu), permitting the conclusion that they are differently colored specimens of the same species.

Widely distributed, since the area of *Antennarius nummifer* extends to the coast of Africa. I am not without doubt that a fish figured by Bleeker (Atlas ichth., vol. 5, pl. 197, fig. 2) under the name *Antennarius coccineus* belongs also to this species. On the other hand, I believe, contrary to the opinion of Jordan and Seale (loc. cit.), the type of this species described by Lesson and Garneri (Voyage de la Coquille, pl. 16, fig. 1) may be easily identified as *Antennarius nummifer,* except that the red color in this figure appears to be slightly exaggerated and the spots and marblings so indistinct as to be hardly visible. These differences, if not due to an inexact drawing, may be accounted for by the great variability of the entire genus, which must be restricted to a small number of widely distributed species. Also *Antennarius nummifer* (Day) (Fishes of India, p. 272, pl. 59, fig. 2, 1878-88) belongs to the species here described.

The significant factor in deciding whether all these should be included in one species is the position of the spots on the head, which are visible in all the figures—differing in size and number, but all in the same position.

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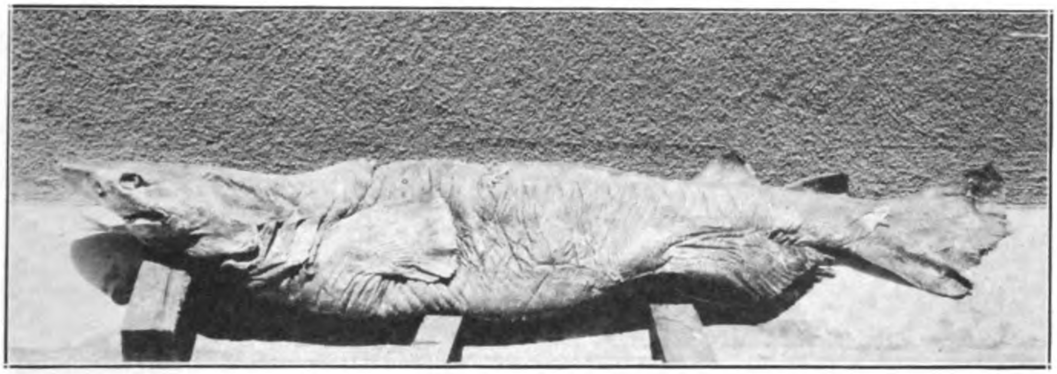

A

B

VIEWS OF ECHINORHINUS COOKEI, NEW SPECIES: *A*, SHOWING LATERAL LINE, THE WHITE BORDER ON PECTORAL FIN DUE TO IMPERFECT PRESERVATION OF THE SKIN; *B*, HEAD AND FRONT PART AS SEEN FROM BELOW. CARANGOID IN MOUTH; SCARS ON THE THROAT PROBABLY CAUSED BY CEPHALOPODS. (PHOTOGRAPH BY KENNETH P. EMORY.)

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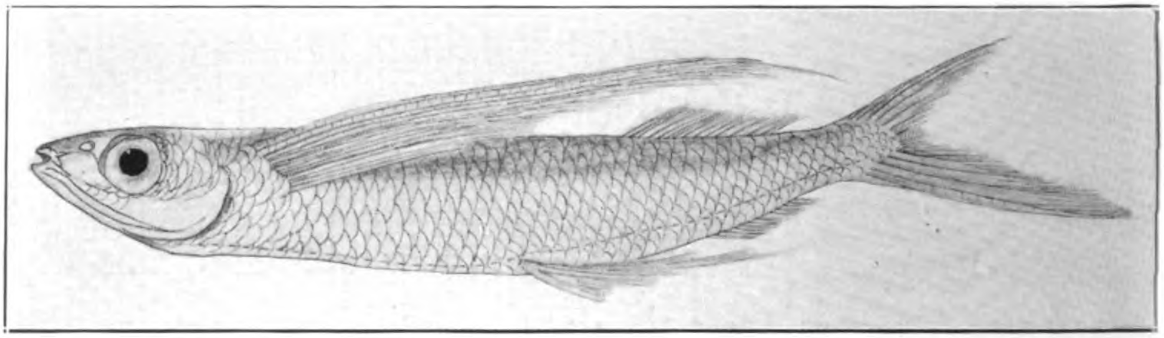

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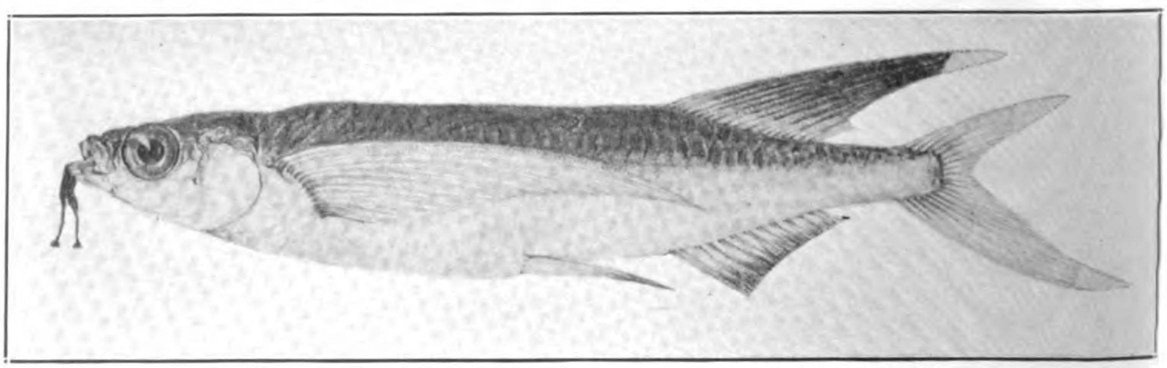

B

A, CYPSELURUS GREGORYI, NEW SPECIES: *B*, PTENONOTUS MELANOGENEION, NEW SPECIES. (DRAWN FROM TYPE SPECIMENS: *A*, BY KENJO YOSHITO; *B*, BY MAXMILIAN HOLLY.)

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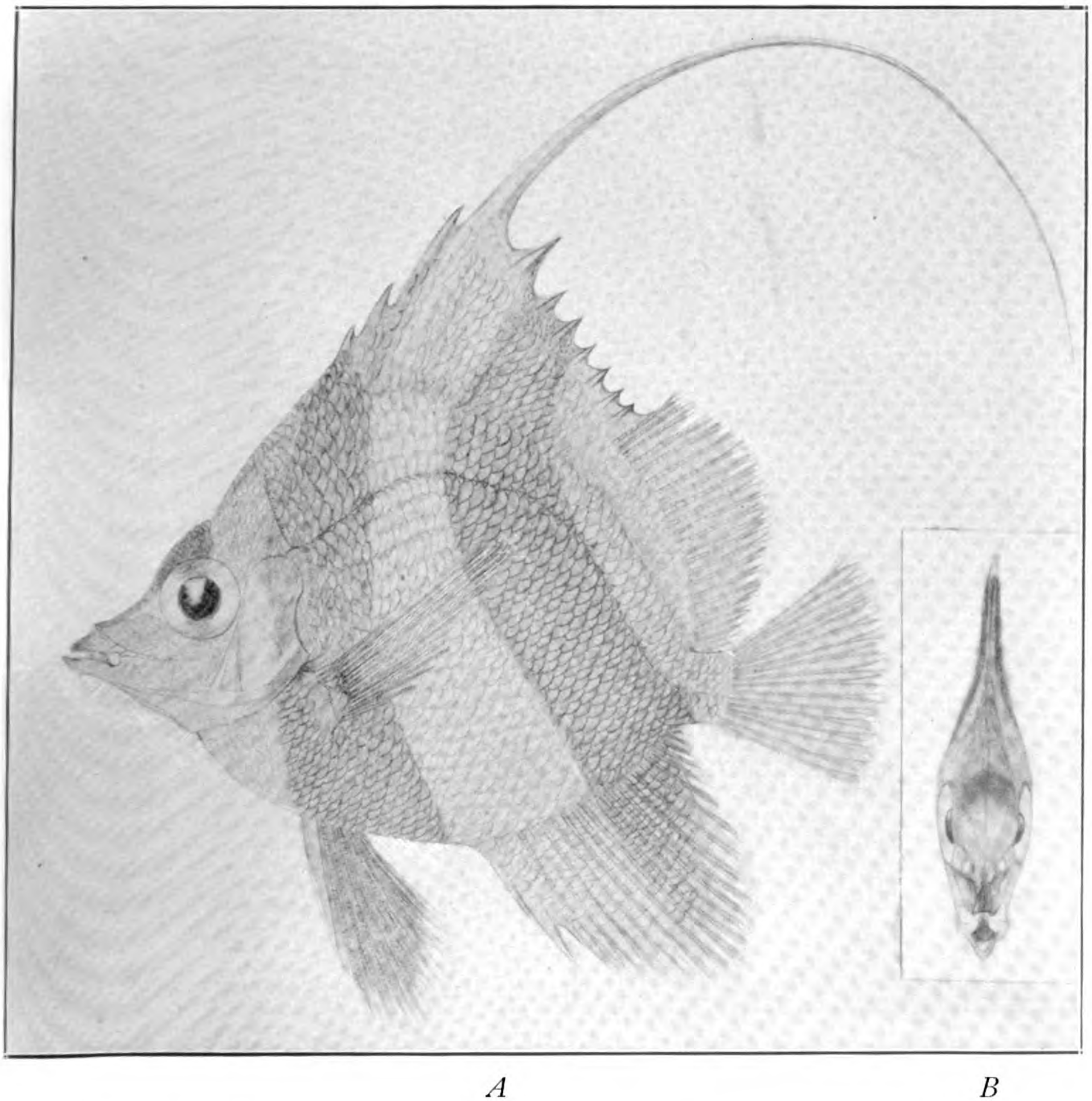

HENIOCHUS ACUMINATUS (LINNAEUS): *A*, SIDE VIEW; *B*, HEAD AS VIEWED FROM THE FRONT. (DRAWN BY YOSHITO KENJO.)

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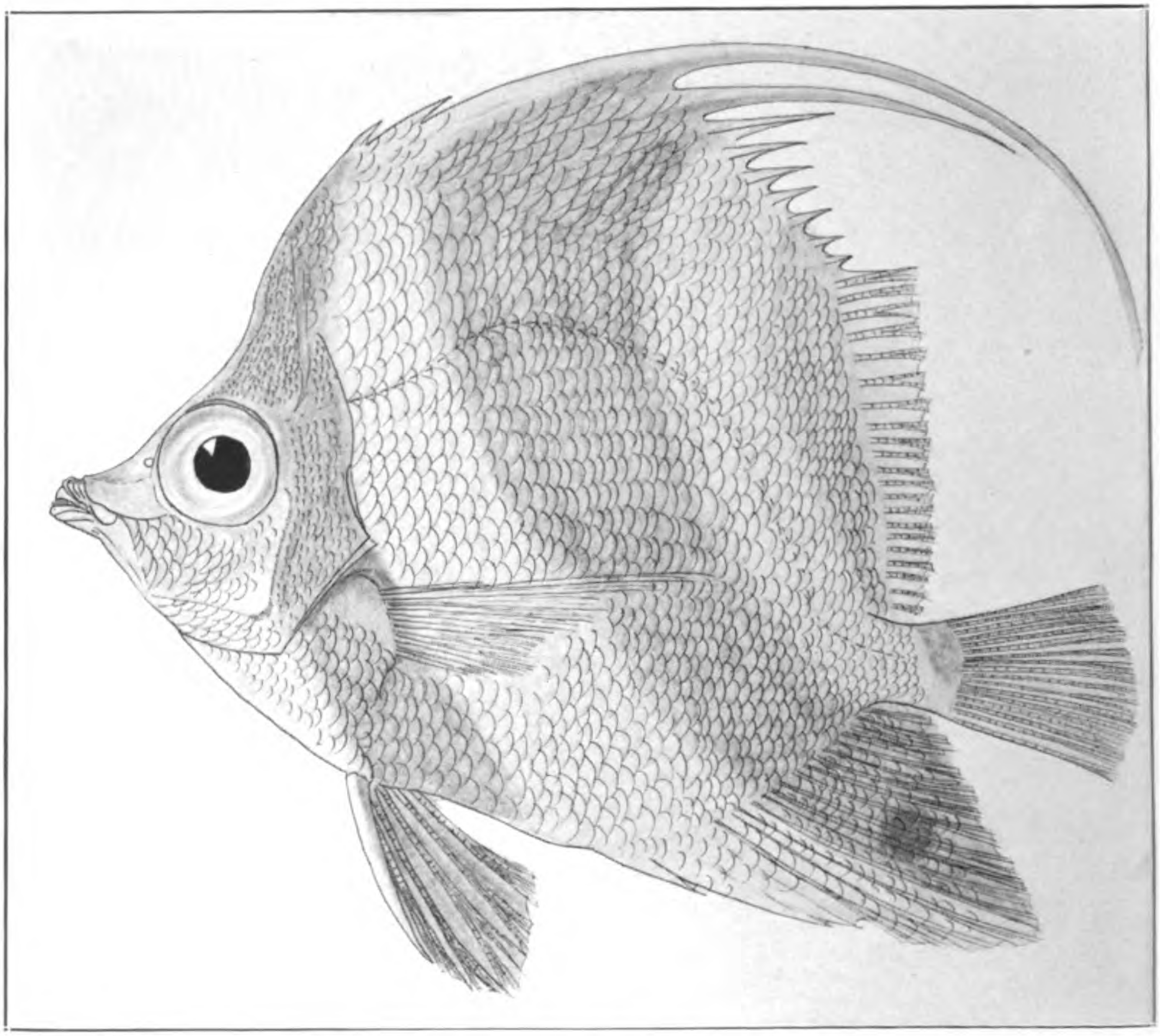

HENIOCHUS CHRYSOSTOMUS (CUVIER AND VALENCIENNES). (DRAWN BY KENJO YOSHITO).

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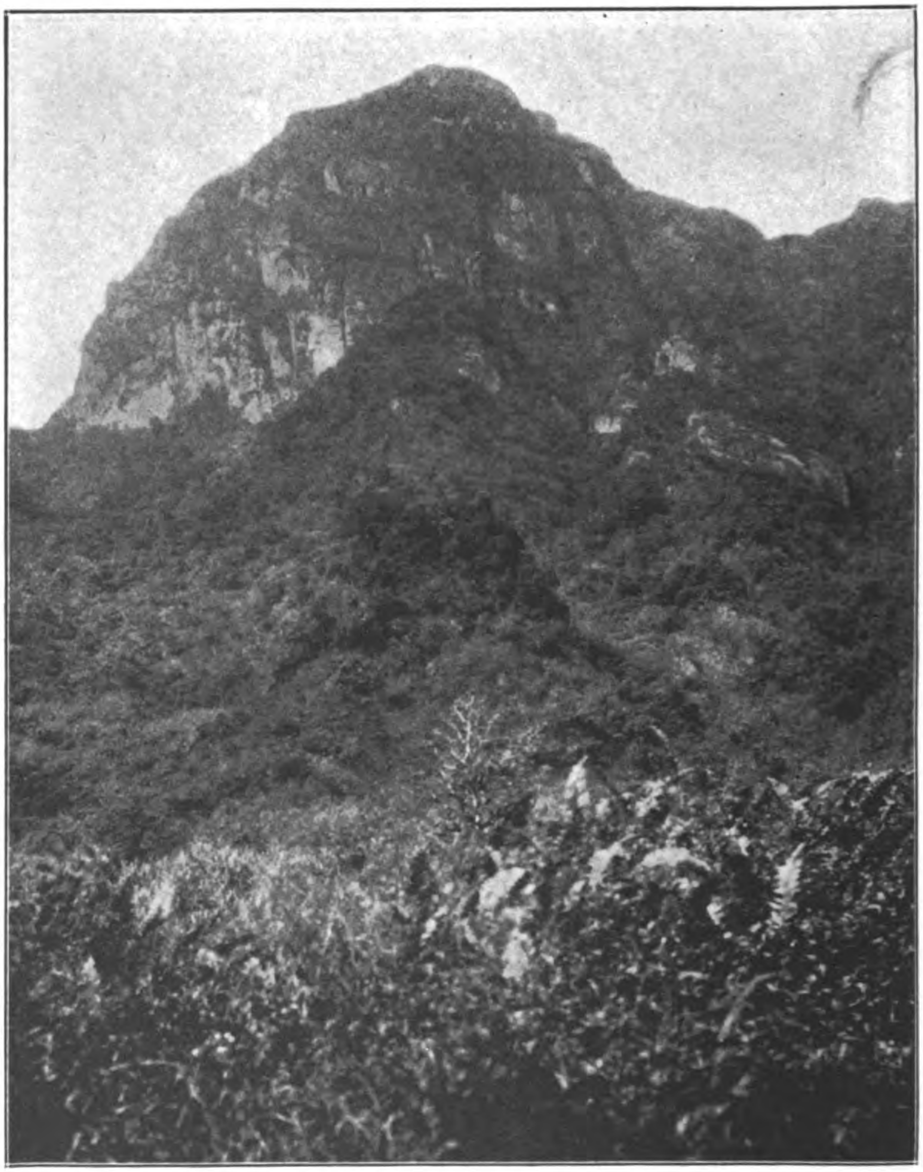

VOMA MOUNTAIN, NAMOSI PROVINCE, VITI LEVU, ALTITUDE 923 METERS. FROM THE SIDES AND SUMMIT OF THIS MOUNTAIN MANY OF SEEMANN'S TYPES WERE COLLECTED.

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NEW PLANTS FROM FIJI—I

BY

JOHN WYNN GILLESPIE

BERNICE P. BISHOP MUSEUM

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New Plants From Fiji—I

By JOHN WYNN GILLESPIE

INTRODUCTION

In the spring of 1927, while a student in botany at Stanford University, I was fortunate in being awarded a Bishop Museum Fellowship in Yale University, which provided for a year's field work in some area in or bordering the Pacific Ocean. After consultation and advice, Fiji was selected, a group of islands of extraordinary interest because of their strategic position with reference to the eastward and northward distribution of the numerous Indo-Malaysian plants in Polynesia. I left California in June, and after short stops in Hawaii and Samoa, arrived in Suva, Fiji, on July 30, 1927, and began work immediately.

I was preceded in my labors by Mr. Harold E. Parks, now Associate Curator of the Herbarium, University of California, an experienced tropical collector. Working under a cooperative arrangement between the University of California and Bishop Museum, Mr. Parks collected intensively for about ten weeks in the eastern part of Viti Levu. His collections and mine were combined as the Parks-Gillespie collection and are being studied conjointly.

Relatively but a small part of Fiji was covered during the eight months of my travels, and even this was all too poorly explored. On Viti Levu, the fine "bush" within the ten-mile radius of Suva was fairly well examined; trips were made to the interior by way of the Navua River; and among the higher mountains specimens were taken from Naitarandamu, Voma, and Vakarongasiu. About two months were spent in the vicinity of Nandarivatu, Tholo North Province, one of the finest locations for botanical study I have ever seen. A short stay on the eastern side of Ovalau, and a few weeks on Taviuni, near Waiyevo, sums up the time spent and localities from which my material was taken. I left Fiji in April, 1928.

The ferns of the Parks-Gillespie collection have been ably treated by Copeland.[1] Certain other groups have been referred to specialists for examination, and the remainder has been the subject of my attention. In this paper, the first of a proposed series, 57 species are described and figured, 41 of which are new.

I am deeply indebted to the many residents who gave assistance during my stay in Fiji, both in official and unofficial capacities. His Excellency Sir Ayre Hutson, Governor of Fiji, gave his sanction to my visit, Dr. J. G. Tothill,

[1] Copeland, E. B., Ferns of Fiji: B. P. Bishop Mus., Bull. 59, 1929.

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Superintendent of Agriculture, was of assistance in many ways, and Mr. Seymour, Colonial Secretary, furnished me with valuable letters of introduction to the District Commissioners of the areas in which I collected. Of these, I especially thank Mr. C. V. Caldwell and Mr. Harley Nott, each of whom was my kind host for periods of weeks.

Financial assistance I gratefully acknowledge from the donors of the original fellowship, from Bernice P. Bishop Museum for additional grants for field work and study, and from the Committee on Graduate Study for a fellowship at Stanford University during the period of herbarium study. As to personal assistance, Dr. E. D. Merrill, Director-in-Chief of the New York Botanical Garden and Consulting Botanist on the staff of Bernice P. Bishop Museum, made preliminary determinations of nearly all the specimens, and has been my constant consultant, having given aid in innumerable ways; to him and to Dr. LeRoy Abrams, Professor of Botany at Stanford University. I give my sincere thanks.

For photographs of type specimens of plants collected by the Wilkes Exploring Expedition and now in the Gray Herbarium, Harvard University, I am indebted to Mr. Rimo Bacigalupi and Mr. Albert N. Steward.

Most of the drawings used for illustration were made by my sister, Helen Gillespie Sperry, to whom I am grateful. They bear her monogram. Uninitialed drawings and the detail studies for all the figures are my own. They were made, for the most part, from material preserved in alcohol.

The types of the species here described have been deposited in the herbarium of the Bernice P. Bishop Museum, isotypes in the herbarium of the University of California and several other institutions.

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MYRSINACEAE

MAESA Forskal

Maesa densiflora Gillespie, species nova (fig. 1).

Arbor parva; foliis glabris, 7-10 cm. longis, 2-3 cm. latis, minute punctatis, oblongo-ellipticis, apice subacutis, basi acutis ad obtusis; inflorescentiis axillaribus, simpliciter racemosis vel depauperato-paniculatis, haud ultra 2.5 cm. longis; sepalis lineatis; extus furfuraceis acutis, margine leviter crenulato; ovario subsphaerico; stylo brevissimo; stigmate bene 3- vel 4-lobato.

A small, glabrous tree 8 to 10 meters high (Parks). Twigs rather stout, brown, terete, with abundant, pale, round lenticels. Leaves 7-10 cm. long, 2-3 cm. broad; blades light-green above, paler beneath, chartaceous, minutely punctate, oblong-elliptic, gradually narrowed upward, apex subacute, base acute to obtuse, lateral nerves 6 to 8 on each side of the midrib, reddish, these and the reticulate veinlets obscure above but evident beneath, margin slightly and irregularly crenate; petioles rather stout, somewhat lepidote, 6-14 mm. long. Inflorescences axillary, racemose or depauperate-paniculate, erect, narrow, sparingly branched, less than 2.5 cm. long, all parts covered with abundant, ferruginous scales; bracts acute; pedicels almost none. Flowers 5- to 7-merous, about 2 mm. long; parts of the prophyllum slightly unequal, the longer about 0.9 mm. long, acute, glabrous within, lepidote without, the margin crenulate and ragged; calyx about 1.2 mm. long, brown, furfuraceous, lobes about 0.6 mm. long, deltoid, acute, lineate, margin slightly crenulate; corolla white, about 1.3 mm. long, obscurely marked with brown or black lines, lobes about 0.7 mm. long, rounded, somewhat scaly within and without, entire; stamens scarcely exserted, about 0.5 mm. long; anthers equal to the broad filaments which are inserted near the base of the corolla-tube; ovary short, flask-shaped; style practically none; stigma deeply 3- or 4-lobed. Fruits unknown.

Fiji, Viti Levu, Tholo North Province, wet canyon in vicinity of Nandarivatu, altitude 1000 meters, July 2, 1927, H. E. Parks. Type no. 20512.

Maesa grandis Gillespie, species nova (fig. 2).

Frutex scandens; foliis chartaceis, glabris, minute punctatis, 13-15 cm. longis, 5.5-7 cm. latis, apice acuminatis, basi rotundatis ad cordatis, margine crenato ad repando-undulato, crenulis obscure mucronatis; inflorescentiis axillaribus, numerosis, 1-2-pinnatim paniculatis, foliis subaequantibus vel brevioribus; sepalis extus lepidotis, acutis, obscure lineatis, margine leviter crenulato; ovario discoideo; stylo crasso.

A glabrous, bushy vine. Twigs attenuate, young parts covered with red-brown scales, verruculose with many small, raised, pale-brown lenticels. Leaves 13-15 cm. long, 5.5-7 cm. broad; blades dark-green above, pale and yellowish beneath, chartaceous, minutely punctate, ovate, apex shortly acuminate, base rounded to cordate, margin crenulate to repand-undulate, the crenulations obscurely mucronate, lateral nerves about 7 on each side of the midrib, conspicuous, arching, tapering, anastomosing near the margin, veinlets reticulate, inconspicuous above, distinct beneath; petioles moderately thick, stout, 2-3 cm. long. Inflorescences very abundant, axillary, somewhat lax, 1- or 2-pinnate-paniculate, up to 9 cm. long, lateral branches often spreading, up to 5 cm. long; bracts acute; pedicels about 1 mm. long. Flowers 5-merous, about 2 mm. long; parts of the prophyllum unequal, the longer about 1 mm. long, the shorter 0.6 mm. long, acute, glabrous within, lepidote without, margin slightly crenulate; calyx glabrous within, lepidote without, 1.3 mm. long, lobes about 0.7 mm. long, deltoid, acute, marked with faint, brown lines, margin slightly crenulate; corolla about 1.5 mm. long, white, marked with conspicuous, brown lines, lobes about 0.8 mm. long, spreading, somewhat scaly within and without, margin entire; stamens

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very short, slightly exserted; anthers oblong, almost sessile; pistil very short, flask-shaped; ovary flattened, brown; style stout; stigma slightly capitate, blunt. Fruits unknown.

Fiji, Viti Levu, Namosi Province, slopes of Voma Mountain near the trail from Namosi village, altitude 600 meters, September 3, 1927, John W. Gillespie. Type no. 2503. Native name; *ngee-ngee,* the *g* being given the hard sound.

Maesa insularis Gillespie, species nova (fig. 3).

Frutex erectus; foliis glabris, 15-23 cm. longis, 4-5 cm. latis, integris, minute punctatis, apice acuminatis ad acutis, basi acutis; inflorescentiis axillaribus, simpliciter paniculatis, haud ultra 5 cm. longis, ramis paucis, patulis, inferioribus usque ad 3 cm. longis, sepalis extus furfuraceis, acutis, obscure lineatis, margine leviter crenulato; ovario conico; stigmate obtuso.

A glabrous shrub, 4 meters high. Twigs slender, terete, lenticels small, pale, inconspicuous. Leaves 15-23 cm. long, 4.5-7 cm. broad; blades dark-green above, pale beneath, thinly chartaceous, minutely punctate, ovate-lanceolate, equally narrowed from the middle to each end, apex acuminate to acute, base acute, entire, lateral nerves 5 or 6 on each side of the midrib, conspicuous above and beneath, veins reticulate, obscure above and rather faint beneath; petioles slender, 2-3 cm. long. Inflorescences axillary, simply paniculate, less than 5 cm. long, lateral branches few, the lower ones up to 2 cm. long; bracts acute; pedicels 1 mm. long. Flowers 5-merous, about 2 mm. long; parts of the prophyllum slightly unequal, the longer about 1 mm. long, acuminate to acute, glabrous within, furfuraceous without, faintly marked with brown lines, margin crenulate and ragged; calyx about 1.3 mm. long, brown, glabrous, rough and scaly on the outside, lobes about 0.7 mm. long, deltoid, acute, obscurely lineate, margin slightly crenulate; corolla about 1.5 mm. long, cream-colored, strongly marked with brown lines, lobes about 0.8 mm. long, reflexed, oval to rounded, broadly obtuse, scaly within and without, margin entire; stamens not exserted, about 0.6 mm. long; anthers small, ovoid, shorter than the slender filaments which are inserted near the base of the corolla-tube; pistil about 0.7 mm. long; ovary ovoid to conical, gradually tapering; stigma obtuse.

Fiji, Viti Levu, Naitasiri Province, in open woods in the vicinity of Nasinu, 9 miles from Suva, altitude 150 meters, October 23, 1927, John W. Gillespie. Type no. 3479.

This species is represented by several other collections. From Gillespie no. 4823, the fruits are described as follows: subglobose or slightly ovoid, dry, hard, brown, longitudinally wrinkled and lineate, calyx-lobes persistent; seeds 12-20, black, shining. Collected on the island of Taviuni, summit ridge on the trail inland from Somosomo.

Maesa lenticellata Gillespie, species nova (fig. 4).

Frutex erectus glaber; foliis 8-12 cm. longis, 2-3 cm. latis, minute punctatis, oblongo-ellipticis, apice acuminatis, basi obtusis; inflorescentiis axillaribus, numerosis, racemosis vel depauperato-paniculatis, haud ultra 5 cm. longis; sepalis extus furfuraceis, acutis, obscure lineatis; margine leviter crenulato; ovario discoideo, stylo crasso; stigmate obscure lobato.

A small, glabrous, erect bush. Twigs stout, terete, marked with very numerous, pale,

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conspicuous, orbicular lenticels. Leaves 8-12 cm. long, 2-3 cm. broad; blades green above, paler beneath, chartaceous, minutely punctate, oblong-elliptic, apex gradually narrowed to acuminate, rounded at the tip, base obtuse, lateral nerves 6 to 8 on each side of the midrib, obscure above but very conspicuous beneath, veins few, reticulate, indistinct above, faint but visible beneath, margin somewhat revolute, slightly crenate; petioles rather stout, grooved, 1.8-2.6 cm. long. Inflorescences axillary, racemose or depauperate-paniculate, less than 4 cm. long, sparingly furfuraceous; bracts acute; pedicels 2-3 mm. long. Flowers 5-merous, about 3 mm. long; parts of the prophyllum slightly unequal, the longer about 1 mm. long, acute, glabrous within, furfuraceous without, obscurely lineate; calyx about 1.4 mm. long, brown, scaly, lobes about 0.7 mm. long, triangular, acute, obscurely lineate, margin slightly crenulate; corolla about 1.7 mm. long, white, marked with brown lines, lobes about 1.2 mm. long, oval or rounded, somewhat scaly within and without, margin entire; stamens included, about 0.5 mm. long; anthers broad, oblong, equal to the filaments; pistil about 1 mm. long, flask-shaped; ovary flattened; style stout; stigma obscurely lobed. Immature fruits 3 mm. long, ovoid, brown, calyx-lobes persistent.

Fiji, Viti Levu, Namosi Province, Naitarandamu Mountain, in dense woods on the summit ridge, altitude 1250 meters, September 28, 1927, John W. Gillespie. Type no. 3149.

Maesa neriifolia Gillespie, species nova (fig. 5).

Frutex erectus; foliis glabris, 7-10 cm. longis, 2-3 latis, ellipticis ad elliptico-lanceolatis, apice acuminatis, basi acutis, nervis primariis utrinque 5 ad 7, distinctis, inter se secundariis nervilliformibus numerosis undulatis praeditis; inflorescentiis axillaribus, paucifloris, depauperato-paniculatis, foliis medio aequantibus; sepalis extus furfuraceis, acutis, manifeste lineatis, margine integro; ovario discoideo; stylo crasso; stigmate obtuso.

A dense, erect bush. Twigs stout, terete, wrinkled in dried material, marked with large, scattered, raised lenticels. Leaves chartaceous, paler beneath than above, 7-10 cm. long, 2-3 cm. broad; blades elliptic to elliptic-lanceolate, apex acuminate, base acute, margin entire, revolute, lateral nerves 5 to 7 on each side of the midrib, conspicuous, reddish, sparingly branched, extending to the margin, the area between filled with very numerous, fine, wavy, parallel nervelets, lightly marked above but very evident beneath; petioles fairly stout, 12-16 mm. long. Inflorescences axillary, depauperate-paniculate, sparsely branched, few-flowered, about one-half the length of the leaves; bracts acute; pedicels about 1 mm. long. Flowers 5- or 6-merous, about 1.7 mm. long; parts of the prophyllum slightly unequal, the longer about 0.8 mm. long, acute, apiculate, glabrous within, furfuraceous without, margin ragged; calyx about 1.2 mm. long, dark-colored, somewhat rough and scaly, lobes about 0.4 mm. long, broad, deltoid or ovate, acute, conspicuously marked with brown lines, margin crenulate; corolla about 1.4 mm. long, white, marked with longitudinal, brown lines, lobes about 1 mm. long, oval or rounded, somewhat scaly within and without, margin entire; stamens slightly exserted, about 0.5 mm. long; anthers ovoid, equaling the filaments; pistil about 0.6 mm. long; ovary red, flattened, disc-shaped; style fairly stout, in many specimens curved; stigma obtuse. Fruits unknown.

Fiji, Viti Levu, Rewa Province, near the summit of Korombamba Mountain, on a steep slope, altitude 550 meters, August 24, 1927, John W. Gillespie. Type no. 2390.

This plant seems to resemble *Maesa persicifolia* A. Gray (see revised description by Mez)[2] in having nervulose markings on the leaves, but in Gray's species the sepals are described as being not at all lineate; in this the markings are very evident.

[2] Mez, Carl, Engler's Pflanzenreich, IV, fam. 236, p. 48, 1902.

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Maesa parksii Gillespie, species nova (fig. 6).

Arbor parva; foliis glabris, minute punctatis, 10-13 cm. longis, 3-4 cm. latis, ellipticis ad oblongo-ellipticis, apice obtusis, basi rotundatis, margine leviter crenato; inflorescentiis laxis, racemosis, plerumque in axillis superioribus, quam foliis paullo brevioribus; sepalis extus furfuraceis, acutis, lineatis, margine crenulati; ovario discoideo; stylo crasso.

A small tree, 6 meters high (Parks), glabrous in all parts. Twigs slender, terete, brown or black with abundant, pale, verruculose lenticels, these most conspicuous near the extremities of the twigs. Leaves 10-13 cm. long, 3-4 cm. broad; blades light-green above, pale beneath, chartaceous, minutely punctate, elliptic to elongate-elliptic, gradually narrowed to the obtuse apex, base rounded or somewhat cordate or truncate, margin slightly crenate, lateral nerves 6 to 8 on each side of the midrib, fairly conspicuous above and beneath, veinlets reticulate, rather obscure; petioles slender, 1.5-2 cm. long. Inflorescences mostly equaling the leaves in length; flowers few, scattered along the axis; bracts acute; pedicels about 1.5 mm. long. Flowers 5-merous, about 1.6 mm. long; parts of the prophyllum slightly unequal, the longer about 0.7 mm. long, acute, glabrous within, brownish furfuraceous without, lineate, margin crenulate; calyx about 1 mm. long, glabrous within, brownish furfuraceous without, lobes about 0.3 mm. long, deltoid, acute, lineate, margin crenulate; corolla about 1.2 mm. long, white, marked with brown lines and spots, lobes spreading, about 0.6 mm. long, oval or rounded, apex somewhat truncate, slightly scaly within and without, margin entire; stamens barely exserted, about 0.6 mm. long; anthers ovoid, equaling the filaments; pistil about 0.8 mm. long; ovary red-brown, disc-shaped; style rather thick; stigma obtuse. Fruits unknown.

Fiji, Viti Levu, Tholo North Province, at the edge of dense forests, vicinity of Nandarivatu, altitude 1100 meters, July, 1927, H. E. Parks. Type no. 20509.

TAPEINOSPERMA Hooker f.

The genera of Myrsinaceae have been arranged by Mez[8] according to the number and arrangement of the ovules on the central placenta. *Tapeinosperma* is described as having rather numerous erect ovules (6-12) affixed near the base of the placenta. In examining the representatives of this genus in the Parks-Gillespie collection, two undescribed species were discovered, which are evidently close relatives of the other well-known Fijian members of that genus, but in each of which there are only five ovules on the placenta, arranged in a single cycle. A recent examination of *T. clavatum* shows that in it the placentas are 3-ovulate. Following Mez's key to the genera on this basis, one arrives at *Discocalyx,* a genus also occurring in Fiji, but to which the plants under consideration certainly do not belong. It would seem that a reconsideration of the characters of *Tapeinosperma* is desirable.

Tapeinosperma cephalophorum Gillespie, species nova (fig. 7).

Arbor parva glabra; foliis usque ad 35 cm. longis et 14 cm. latis, coriaceis, anguste obovatis ad late oblanceolatis, apice obtusis vel rotundatis, basi acuminatis; petiolis fere nullis; inflorescentiis lateralibus, capitatis, 5-9-floris; floribus sessilibus; peduncilis 3 cm. longis, bracteis ad 16 mm. longis, 18 mm. latis, suborbicularis; calycibus circiter 8 mm.

[8] Mez, Carl, Engler's Pflanzenreich, IV, fam. 236, 1902.

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longis, late ellipsoideis, rotundatis; corolla crassa, 12 mm. longa, lobis 8 mm. longis, late ellipticis, retusis; fructibus subglobosis, laevibus, circiter 24 mm. diametro.

A small tree, glabrous throughout; twigs up to 1 cm. thick, blunt at the apex; leaf-scars about 8 mm. broad, triangular to suborbicular, raised, conspicuous. Leaves up to 35 cm. long, 14 cm. broad; blades coriaceous, punctate, yellowish-green when dry, narrowly obovate to broadly oblanceolate, broadest well above the middle and gradually narrowed to the acuminate base, lateral nerves not at all conspicuous, straight, arching and anastomosing towards the margin, about 20 on each side of the midrib, veinlets delicately traced, intricately reticulate above and beneath; petioles almost none, broad, stout, winged. Inflorescences lateral, in the uppermost axils, densely capitate, 5-9-flowered, each flower subtended and partially enclosed by a bract; peduncles downward curved, stout, about 3 cm. long. Flowers dark-red, sessile, subglobose; bracts up to 16 mm. long, 18 mm. broad, suborbicular, deeply cupped, round and curving over the flower, chartaceous, punctate; calyx thickened, about 8 mm. long, lobes about 6 mm. long, broadly elliptic, rounded; corolla much thickened at the base, about 12 mm. long, punctate, lobes about 8 mm. long, broadly elliptic, retuse; anthers about 3 mm. long, 2 mm. broad, thick, practically sessile; pistil about 5 mm. long; ovary ovoid; style stout, thick; stigma flattened, discoid. Fruits (Gillespie no. 4442) subglobose, dark-red, about 24 mm. in diameter, minutely apiculate, soft, fleshy; seed about 18 mm. long and broad, deeply 5-lobed, the lobes angular and toothed, integument chartaceous, endosperm white, horny; calyx persistent.

Fiji, Ovalau, near the summit of the main range west of Levuka, altitude 500 meters, January 26, 1928, John W. Gillespie. Type no. 4441. Fruits from a near-by tree (Gillespie no. 4442).

Tapeinosperma clavatum Mez (fig. 8).

Tapeinosperma clavatum Mez, in Engler's Pflanzenreich, IV, fam. 236, p. 164, 1902.

"Ramuli crassi, glabri. Folia petiolis ± 12 mm. longis stipitata, anguste vel oblongo-elliptica, basi longe apice brevius longiusve acuta vel hic raro obtusiuscula, ± 150 mm. longa, 50 mm. lata, chartacea, glabra, utrinque tenuiter prominulo-costulata et supra prope marginem laxe minuteque retata, punctis multis atris plerisque brevissime lineoliformi-elongatis aucta. Inflorescentiae axillares, submultiflorae, anguste pyramidatae, paupere tripinnatim panniculatae, minute pubescentes, foliis haud multo breviores, ramulis flores valde abbreviate racemosos gerentibus, pedicellis 2-3 mm. longis, validis, apicem versus sensim clavatim incrassatis; flores non nisi imperfecti cogniti; sepala coriacea, pauci-punctata; petala percrassa gomphacea; antherae sessiles; ovarium glabrum, ellipsoideum stylo subaequilongo bene crasseque cylindrico, stigmate conico. Fidji-Insel Ovalau; im Gebirge 700 m. ü. M., ein kleiner Baum (Horne n. 52, 180).—Blüht Dezember, Januar (Herb. A. Gray, Kew)."—Mez.

One specimen, Gillespie no. 4513, from the mountains of Ovalau above Levuka, altitude 500 meters, was collected very close to the type locality, where the plants are fairly common. The following description of the floral parts, imperfect in Horne's specimens, was made from alcoholic material:

Calyx conic, about 4 mm. across, lobes scarcely 1 mm. long, very broadly obtuse, emarginate, ciliate, sparingly black-punctate; corolla about 6 mm. in diameter, 6 mm. long, lobes outwardly convex, thickened, about one-fourth united, asymmetric, ovate, shortly acuminate, minutely punctate towards the margin; stamens sessile, about 1 mm. long, triangular-pyramidal; pistil about 3 mm. long, flask-shaped; stigma discoid; placenta ovoid, 3-ovulate; fruits about 6 mm. in diameter, pyriform, strongly apiculate, punctate.

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Also represented by Gillespie nos. 2674, 3699, 4037, 4444, and 4645, in some of which the flowers are somewhat smaller. It is interesting to note that the name *da see a,* given to this plant by the natives of Namosi, is the same as that recorded by D. Yeoward for *T. megaphyllum* (description by Hemsley in Kew Bull., no. 85, p. 6, 1894).

Tapeinosperma punctatum Gillespie, species nova (fig. 9).

Arbor parva glabra; foliis ad 28 cm. longis, 9 cm. latis, chartaceis, dense punctatis, oblongo-ellipticis ad oblongo-obovatis, apice rotundatis; petiolo 15-20 mm. longo; inflorescentiis lateralibus, capitatis, circiter 6-floris; floribus bracteatis, sessilibus; pedunculis 6 cm. longis; calycibus 8 mm. longis, lobis manifeste emarginatis, 5 mm. longis, 3 mm. latis; corolla 7 mm. longa, lobis late ellipticis, rotundatis, crassis.

A small tree, glabrous throughout; twigs up to 1 cm. thick, abruptly tapering or blunt at the apex, leaf-scars about 5 mm. broad, triangular to suborbicular, slightly raised, rather conspicuous. Leaves up to 28 cm. long, 9 cm. broad; blades chartaceous to somewhat coriaceous, densely punctate, yellowish-green when dry, oblong-elliptic to oblong-obovate, apex broadly obtuse to rounded, gradually narrowed from above the middle to the acuminate base, lateral nerves about 15 on each side of the midrib, not at all conspicuous, ascending, many times branched, with the veinlets forming delicate reticulations; petioles broad, stout, 15-20 mm. long. Inflorescences lateral, borne near the extremities of the twigs, capitate, about 6-flowered, each flower apparently subtended by a bract of which only the scar is visible in the specimens examined; peduncles downward curved, moderately stout, about 6 cm. long. Flowers chocolate-brown, sessile; calyx about 8 mm. long, furfuraceous within and without, lobes broadly elliptic, strongly emarginate, about 5 mm. long, 3 mm. broad, somewhat thickened; corolla about 7 mm. long, lobes broadly elliptic, rounded, thickened, about 3 mm. long, marked with black spots and lines which are conspicuous on the inside; stamens about 2.8 mm. long; anthers broad; filaments very short, flattened; pistil about 4 mm. long; style rather thick, about 2 mm. long; stigma discoid. Fruits unknown.

Fiji, Viti Levu, Tholo North Province, Nandarivatu, slopes of Loma Langa Mountain, altitude 1050 meters, November 21, 1927, John W. Gillespie. Type no. 3919. Gillespie no. 3696 represents another collection with somewhat larger flowers.

DISCOCALYX Mez

Discocalyx divaricata Gillespie, species nova (fig. 10).

Arbor parva; ramulis gracilibus, basi incrassatis; foliis 9-12 cm. longis, 1.5-2.5 cm. latis, supra glabris, subtus sparsim rufo-hirsutis, oblongis ad oblongo-lanceolatis, apice acutis ad acuminatis, basi truncatis ad paullo cordatis; inflorescentiis divaricatis, ad 3.5 cm. longis, paucifloris; pedunculis 2 cm. longis; calycibus 2 mm. diametro; lobis triangularis, acutis, bene ciliatis, 1 mm. longis; corolla 3 mm. longa, lobis ellipticis, rotundatis, nigro-punctatis.

A small tree, about 4 meters tall (Parks), for the most part glabrous. Twigs slender, smooth, terete, their bases characteristically enlarged. Leaves few, clustered at the extremities of the twigs, 9-12 cm. long, 1.5-2.5 cm. broad; blades green and glabrous above, sparsely pilose with reddish hairs beneath, minutely punctate, entire, chartaceous, oblong to oblong-lanceolate, apex gradually narrowed, sometimes slightly acuminate, base truncate to slightly cordate, lateral nerves ascending, about 7 on each side of the midrib, obscure; petioles slender, 1.3-2 cm. long, slightly pilose. Inflorescences in the uppermost axils, divaricate, up to 3.5 cm. long, few-flowered; peduncles slender, about 2 cm. long,

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pilose; pedicels about 2 mm. long, pilose. Flowers chocolate-brown; calyx about 2 mm. in diameter, glabrous within, furfuraceous without, lobes broadly spreading, about as long as the tube, more or less triangular, acute, margin thickly ciliate; corolla about 3 mm. long, 4 mm. in diameter, glabrous, lobes about 2.4 mm. long, 1.3 mm. broad, broadly elliptic, rounded, black-punctate at the margin, anthers about 1 mm. long; pistil about 1.3 mm. long; style slender; stigma discoid; ovules apparently 3. Fruits (Gillespie no. 3843) subglobose, attenuate at each end, about 5 mm. in diameter, decidedly apiculate, hard, glabrous, obscurely 5-ridged, especially at the apex.

Fiji, Viti Levu, Tholo North Province, thick forests in the vicinity of Nandarivatu, altitude 1300 meters, July, 1927, H. E. Parks. Type no. 20592, a flowering specimen. Also represented by Parks no. 20534, Gillespie no. 4069.1, both from the same general area. The fruits are described from Gillespie no. 3843, collected in the vicinity of Nandarivatu, altitude 900 meters. Native name: ***mbulumbulu***.

Discocalyx multiflora Gillespie, species nova (fig. 11).

Arbor parva, calycis lobis exceptis glabra; ramulis basi incrassatis; foliis 7-10 cm. longis, 2.5-3.5 cm. latis, ellipticis ad obovatis, apice acutis ad obtusis, basi acutis; inflorescentiis plurifloris, ad 18 cm. longis; pedunculis 7-10 cm. longis, crassis; calycibus 2 mm. diametro, lobis subtriangularis, manifeste ciliatis; corolla 3 mm. longa, lobis crassis, late ellipticis, acutis, maculatis.

A small tree, glabrous except the calyx-lobes. Twigs fairly stout, smooth, terete, pale-brown, their bases characteristically enlarged. Leaves 7-10 cm. long, 2.5-3.5 cm. broad; blades green above, dull and yellowish beneath, minutely punctate, entire, rather thick, chartaceous, elliptic to oblong-elliptic or obovate, apex acute, often narrowly rounded or obtuse, base acute, slightly decurrent, lateral nerves somewhat ascending, about 12 on each side of the midrib, these and the veinlets finely marked above and beneath; petioles fairly stout, 5-10 mm. long. Inflorescences ample, many-flowered, borne on special branchlike peduncles, up to 18 cm. long, much surpassing the leaves; pedicels about 2 mm. long, minutely furfuraceous; bracts about 1 mm. long, acute; calyx about 2 mm. in diameter, glabrous within, verruculose and minutely furfuraceous without, lobes about 1 mm. long, subtriangular, broadly spreading, conspicuously ciliate; corolla about 3 mm. long, glabrous, lobes about 2 mm. long, rather thick, broadly elliptic, acute, marked on the outside, and much more conspicuously within, with large, glandular spots; anthers about 1.4 mm. long, more or less truncate, broad, marked with large protuberences on the adaxile surface, practically sessile; pistil about 1.2 mm. long; style rather slender; stigma more or less discoid; ovules usually 3. Fruits unknown.

Fiji, Viti Levu, Namosi Province, near the summit of Naitarandamu Mountain, altitude 1100 meters, September 28, 1927, John W. Gillespie. Type no. 5113.

SAPOTACEAE

PLANCHONELLA Pierre

Planchonella vitiensis Gillespie, species nova (fig. 12).

Arbor parva, ramulis junioribus puberulentis, mox glabris, gracilibus; foliis 7-10 cm. longis, 2-3 cm. latis, junioribus utrinque hirsutis demum glabris, oblongo-obovatis ad elliptico-obovatis, basi longe acuminatis; petiolis 1 cm. longis; floribus axillaribus, fasciculatis; pedicellis 4-8 mm. longis, hirsutis; corolla 1.2 mm. longa; lobis 8 mm. longis,

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subtriangularis, rotundis; calycibus 1.2 mm. longis, breviter connatis, extus dense hirsutis, intus glabris, ad marginem ciliatis; ovario hirsuto; fructibus glabris, oblongo-ovoideis, usque ad 12 mm. longis, apiculatis.

A small tree, young parts and flowers puberulent with burnished-coppery hairs; twigs glabrescent, slender, smooth, terete; leaf-scars roundish, raised. Leaves well distributed along the twigs, 7-10 cm. long, 2-3 cm. broad; blades yellowish-green and hairy on both sides when young, at length glabrous, thickly chartaceous, oblong-obovate to elliptic-obovate, apex acute, not at all rounded, base long-acuminate; lateral nerves inconspicuous, these and the veinlets delicately traced beneath; petioles about 1 cm. long, slender. Flowers axillary, fascicled; pedicels moderately stout, 4-8 mm. long, hairy; corolla glabrous, about 1.2 mm. long, lobes 1 mm. broad, broadly triangular, rounded, entire or obscurely crenulate, glabrous; stamens 10, all apparently rudimentary; calyx about 1.2 mm. long, 2 mm. broad, lobes rather thick, shortly united, densely hairy without, glabrous within, rounded, margin distinctly ciliate; ovary about 2 mm. in diameter, densely hairy; style about 1 mm. long, stout or slender; stigma obtuse. Fruits (immature?) glabrous, green, oblong-ovoid, about 12 mm. long, 6 mm. thick, apiculate.

Fiji, Ovalau, on rocky knobs, mountains 3 miles northwest of Levuka, altitude 150 meters, February 1, 1928, John W. Gillespie. Type no. 4546.

BURCKELLA Pierre

Burckella thurstonii (Hemsley) H. J. Lam (fig. 13).

Bassia thurstonii Hemsley ex Hooker's Icones plantarum, vol. 26, pl. 2569, 1899.

Burckella thurstonii (Hemsley) H. J. Lam: Jardin Botanique de Buitenzorg, Bull., ser. 3, vol. 7, p. 259, 1925.

"*Arbor* ramulis floriferis crassissimis. *Folia* ad apices ramulorum conferta, distincte petiolata, valde coriacea, obovato-lanceolata, 5-10 poll. longa, apice rotunda, basi cuneata, supra glabra vel cito glabrescentia, subtus ferrugineo-tomentosa, venis primariis lateralibus utrinque circiter 15-17 subtus elevatis. *Flores* numerosi, fasciculati, atque pedunculi circiter pollicares ferrugineo-tomentosi, quam pedunculi paullo breviores. *Sepala* 4, crassissima, ovato-rotundata. *Corolla* alte 8-lobata, lobis obovato-spathulatis intus infra medium pilosis. *Stamina* circiter 40, filamentis valde pilosis. *Ovarium* glabrum, 4-loculare, stylo breviter exserto. *Fructus* ignotis."—Hemsley.

This species is represented by Gillespie nos. 3430 and 4515, from Viti Levu, Naitasiri Province; and Ovalau, respectively. The fruits, which were lacking in Horne's specimen from which the original description was made, are described from Gillespie no. 3430 as follows: fruiting pedicel about 4 cm. long, very thick, stout; calyx thickened, more or less lignified; fruits obovate, pyriform, soft, up to 7 cm. long, about 3.5 cm. thick, longitudinally grooved, dull-green, with rough, russet markings.

LUCUMA Molina

Lucuma vitiensis (A. Gray) Gillespie, combinatio nova (fig. 14).

Sapota (?) vitiensis A. Gray, Amer. Acad. Arts and Sci., Proc., vol. 5, p. 328, 1862.

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Sideroxylon vitiensis Burkill, Linnean Soc., London, Botany, Jour., vol. 35, p. 44, 1901.

"Glabra, foliis oblongis seu obovato-oblongis obtusis vel retusis subcoriaceis reticulatis (4-6-poll. longis) basi in petiolum longiusculum attenuatis; fructu subsessili globoso 3-4-spermum (pollicem diametro).—Ovalau, Feejee Islands, on the coast."—A. Gray.

Mr. Burkill, in referring this species to the genus *Sideroxylon,* has given an amplified description from specimens in the collection of Mr. Crosby from the islands of Eua and Vavau, Tonga, and in that of Horne from the mountains of Ovalau, Fiji. Apparently he did not see the fruits, which are described from Gillespie no. 4559 as follows: fruits soft, glabrous, green with whitish bloom, globose, about 2.5 cm. in diameter, 3-5-seeded; seeds about 16 mm. long, 7 mm. broad, pale-yellow, shining.

This species is represented in the Parks-Gillespie collection by Gillespie nos. 4487, 4494, and 4559, all from Ovalau. It has not been found elsewhere in Fiji.

EBENACEAE

MABA Forster

Maba nandarivatensis Gillespie, species nova (fig. 15).

Arbor parva, subglabra; ramulis gracilibus, nigris, partibus junioribus floribusque adpresse pubescentibus; foliis chartaceis, 5-8 cm. longis, 1.5-3 cm. latis, oblongo-ellipticis ad ovatis, apice acutis, basi obtusis, acriter decurrentibus, margine bene undulato; nervis obscuris; floribus masculis solitariis vel trinis; staminibus 10, 2-seriatis; fructibus rubris vel flavis, subglabris, glaucis, circiter 14 mm. longis, ellipsoideis ad obovoideis, obliquis, apiculatis; pericarpio chartaceo; seminibus 4 ad 6; calycibus fructiferis glabris vel sparse pubescentibus, cupulatis, circiter 6 mm. diametro, lobis obtusissimis.

A small, subglabrous tree, with slender, rough, blackened twigs; young parts and flowers appressed-pubescent. Leaves 5-8 cm. long, 1.5-3 cm. broad; blades chartaceous, often pale or yellowish, oblong-elliptic to more or less ovate, apex narrowed, acute, the tip rounded; base obtuse, sharply decurrent, margin notably undulate, especially when dry, nerves and veins obscure or indistinctly reticulate; petioles about 3 mm. long. Male flowers solitary or in 3's (immature), about 3 mm. long; calyx appressed-puberulent without, lobes acute; corolla the same, but silky-haired without; stamens 10, in 2 series, disc at the base covered with tawny hairs. Female flowers unknown. Fruits dry, solitary, red or yellow, subglabrous, glaucous, about 14 mm. long, ellipsoid to obovoid, oblique, shallowly channeled, apiculate; pericarp chartaceous, fragile; partitions membranaceous; seeds 4 to 6, about 1 cm. long, the axis curved; testa brown, sculptured; fruiting pedicel 1 mm. long, thickened; fruiting calyx glabrous or sparsely pubescent, cupulate, about 6 mm. across, lobes about 3 mm. long, very obtuse.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, valley of the Singatoka River, altitude 900 meters, November 17, 1927, John W. Gillespie. Type no. 3848.

This species is closely related to *Maba sandwicensis* A. DC., which also is found in Fiji, but differs in its thinner, undulate leaves, smaller fruiting

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calyx, and in the number of stamens in the male flowers. Other numbers from the same locality are: Parks no. 20602, Gillespie no. 3764. It is characteristic of the upper ridges of the high forest, the small trees, attractive with their bright-colored fruits, forming a part of the "overstocked plantation" of Gibbs [4]. The native name is *vau ndrai ni singa.* Isalla of Nandarivatu, an accomplished Fijian herbalist, says that a decoction of the fruits is good for ailments of the back!

DIOSPYROS Linnaeus

Diospyros longisepala Gillespie, species nova (fig. 16).

Arbor parva; foliis glabris, 8-14 cm. longis, 3.5-6 cm. latis, elliptico-lanceolatis, apice et basi acutis; fructibus subglobosis, haud punctatis, 2.5 cm. diametro, crasse pedicellatis; calycibus fructiferis ligneis, 22 mm. diametro, disco 12 mm. diametro, plano, haud concavo, lobis 5, anguste oblongis, obtusis, 11 mm. longis, 3 mm. latis, patulis.

A small tree. Twigs glabrous, terete, dark colored, roughened with round, raised lenticels. Leaves glabrous, 8-14 cm. long, 3.5-6 cm. broad; blades chartaceous, sparingly punctate, elliptic-lanceolate, acute at both ends, lateral nerves about 6 on each side of the midrib, veinlets reticulate, fairly conspicuous above and beneath; petioles rather stout, about 12 mm. long. Inflorescences unknown. Fruits solitary, hard, dull-yellow, glabrous, not punctate, slightly apiculate, globose at maturity, about 2.5 cm. in diameter; pericarp brittle, about 0.4 mm. thick; pedicels thick, 2-3 mm. long; fruiting calyx about 22 mm. in diameter to the extremities of the calyx-lobes, woody at the base, which is plane, not at all concave, disc about 12 mm. in diameter; lobes 5 (in the single fruit seen), narrowly oblong, obtuse, about 11 mm. long, 3 mm. broad, elongate, spreading; seeds 4, about 14 mm. long, 8 mm. broad, black, endosperm white, not ruminate.

Fiji, Viti Levu, Tholo North Province, slopes of Loma Langa Mountain, in open woods, altitude 950 meters, December 20, 1927, John W. Gillespie. Type no. 4360 .

Diospyros vitiensis Gillespie, species nova (fig. 17).

Arbor parva, subglabra; foliis 8-14 cm. longis, 4-7 cm. latis, ellipticis, subcoriaceis, apice obtusis, basi acutis; floribus feminis breviter crasseque pedicellatis; calycibus junioribus 12 mm. diametro, lobis reflexis, crassis, 4-5 mm. longis; fructibus globosis, laevibus, 2.5 cm. diametro; calycibus acrescentibus, apud fructu ligneis, crassis, 14 mm. diametro, concavis, depresso-cupuliformibus, lobis triangularis, 6 mm. longis, obtusis ad acutis, crassis, valde reflexis.

A small, nearly glabrous tree, with rough, dark bark. Twigs glabrous or slightly puberulent when young, roughened with conspicuous, dark lenticels; leaf-scars large, raised. Leaves glabrous, 8-14 cm. long, 4-7 cm. broad; blades rather thick, subcoriaceous, black-punctate, elliptic to elliptic-lanceolate, apex obtuse to shortly acute, base acute, lateral nerves about 5 on each side of the midrib, more conspicuous beneath than above, veinlets coarsely reticulate, obscure; petioles stout, rough, 5-10 mm. long. Male inflorescences unknown; female flowers (Gillespie no. 4207) immature, solitary or in pairs, on short, thick pedicels; calyx 12 mm. in diameter, lobes reflexed, thick, 4-5 mm. long; corolla at least 5 mm. long, lobes ovate, twice as long as the tube. Fruits solitary, hard, dull, yellowish-green, glabrous, smooth, apiculate, oblong-globose when young, globose at maturity, about 2.5 cm. in diameter; pericarp brittle, about 0.4 mm. thick; pedicel very

[4] Gibbs, L. S., A contribution to the montane flora of Fiji: Linnean Soc. London, Botany, Jour., vol. 39, p. 206, 1909.

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thick, 3-4 mm. long; fruiting calyx woody, about 14 mm. in diameter, thickened, border somewhat raised to receive the fruit, lobes usually 4, obtuse to acute, triangular, about 6 mm. long, very thick, strongly reflexed. Seeds 8, closely packed together, 15 mm. long, 6 mm. broad, black, shining, testa irregularly striate, raphe slender, endosperm white, not ruminate.

Fiji, Viti Levu, Namosi Province, Naitarandamu Mountain, at place called Navunitaruilau, on wooded ridge between the water-sheds of the Wainimala and the Wainikoroluva, altitude 900 meters, September 27, 1927, John W. Gillespie. Type no. 3083. Native name: *mbole*.

I have recorded this as a small tree, up to 10 meters high, with dense foliage and spreading crown, not at all common. Other collections of this species are: Gillespie nos. 2950 and 4207, all found along streams at fairly high elevations. I have compared specimens collected by me with those collected by Professor W. A. Setchell on Tutuila Island, Samoa, of *D. samoensis* A. Gray, to which this species is related. The branches and twigs of *D. vitiensis* are much rougher, the leaves are larger and thicker, and the calyx is of smaller diameter, its lobes being thicker and more strongly reflexed.

SYMPLOCACEAE

SYMPLOCOS Jacquin

Symplocos leptophylla (Brand) Turrill (fig. 18).

Turrill [5] describes this plant as follows:

Arbor ramis glabris vel junioribus leviter puberulis sicco brunneis vel flavo-brunneis vel junioribus flavo-viridibus. *Folia* oblongo-elliptica, apice acuminata, acumine usque ad 1 cm. longo, basi acuta, usque ad 12 cm. longa (acumine incluso) et 5 cm. lata, integra vel leviter crenata, nervis lateralibus utrinque circiter 7 pagina superiore subprominentibus inferiore prominentibus, costa supra impressa infra valde prominente; petiolus usque ad 1.5 cm. longus, fere glaber. *Inflorescentia* axillaris vel terminalis, usque ad 4 cm. longa, simplex vel ramosa, puberula; bracteae ovatae, 2 mm. longae, 1.5 mm. latae, extra puberulae, intra glabrae; bracteolae ovatae, 1.3 mm. longae, 1 mm. latae, extra puberulae, intra glabrae; pedicelli circiter 1 mm. longi. *Sepala* 5, oblongo-ovata, obtusa, 2.25 mm. longa, 1.25-1.5 mm. lata, extra adpresse puberula, intra glabra, margine ciliate. *Petala* 5, late ovata, obtusa 3 mm. longa, 2.5 mm. lata. *Stamina* [multa], indistincte pentadelpha. *Ovarium* semi-inferum; stylus usque ad 1.5 mm. longus. *Fructus* immaturatus ovoideo-ellipsoideus, superne contractus, calyce persistente coronatus, glaber.—*S. stawelii*, F. Muell., var. *leptophylla*, Brand in Engler, Pflanzenreich, iv., 242, p. 37. *S. spicata*, Seem. in Fl. Vit. p. 153, non Roxb.

Fiji (Kandavu), *Seemann*, 294.

This elegant little tree is common in the forests of Fiji, from sea level to the summits of the highest mountains. The leaves are generally 12-18 cm. long and about 6 cm. broad. As stated by Turrill, numerous well-marked varieties occur. The form with oblong-elliptic, acuminate leaves which are

[5] Turrill, W. B., A. contribution to the flora of Fiji: Linnean Soc. London, Botany, Jour., vol. 43, p. 30, 1915.

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subcoriaceous and turn yellow in drying, is distributed throughout Viti Levu and Ovalau, being represented in our collections by Gillespie no. 2006 (Naitasiri Province), Gillespie no. 3902 (Thol-i-Nandarivatu, Tholo North Province), Gillespie no. 3918 (Loma Langa Mountain, Tholo North Province), and Gillespie no. 4431 (Mountains of Ovalau). In Gillespie no. 5115, from Namosi Province, summit of Naitarandamu Mountain, the leaves are almost as broad as long, conspicuously puberulent beneath, and are subcordate at the base. In the hills around Namosi village were found Gillespie nos. 2699 and 2846, with bright-green, chartaceous leaves which do not turn yellow in drying, and finally may be noted Gillespie no. 4113, from Tholo North Province, summit of Mount Victoria, the leaves of which are glabrous, submembranaceous, and less than 9 cm. long.

The bark is thin and brown and peels easily, exposing the very white wood beneath. Native names: *vula wai, ravu levu, wai ni, mari, ai soó soo.*

OLEACEAE

JASMINUM (Tournefort) Linnaeus

Jasminum unifoliolatum Gillespie, species nova (fig. 19).

Frutex scandens glaber; foliis 4-6 cm. longis, 1-1.8 cm. latis, unifoliolatis, chartaceis, lanceolatis ad oblongo-lanceolatis, apice longe acuminatis, interdum mucronatis, basi rotundatis ad late acutis, trinerviis; nervis marginalis obscuris; petiolo 2-3 mm. longo, articulo petioli obscuro; pedunculis 2-7 mm. longis; bracteis 1.5 mm. longis, acuminatis; calycibus fructiferis 2-2.5 cm. longis; receptaculis 3 mm. longis, 2.5 mm. diametro, lobis vix 1 mm. longis, abrupte acuminatis; loculis divaricatis.

A woody vine (Parks), glabrous throughout; twigs terete, pale-brown, very slender. Leaves opposite to subopposite, 4-6 cm. long, 1-1.8 cm. broad, 1-foliolate; blades thinly chartaceous, lanceolate to oblong-lanceolate, apex long acuminate, sometimes mucronate, base rounded to broadly acute, 3-nerved, the two marginals obscure. Flowers unknown. Fruiting peduncles 2-7 mm. long; bracts 2 to 4 pairs, about 1.5 mm. long, acuminate; fruiting calyx 2-2.5 cm. long, limb tubular, gradually enlarged to the receptacle which is about 3 mm. long, 2.5 mm. in diameter, lobes 4, scarcely 1 mm. long, abruptly acuminate. Fruits 1- or 2-loculed; locules divaricate, about 1 cm. long, pear-shaped, black, shining; seeds solitary in each locule, flattened, ovate, about 5 mm. long, brown, shining.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, altitude 1200 meters, July, 1927, H. E. Parks. Type no. 20667.

APOCYNACEAE

ALYXIA R. Brown

After studying the species of *Alyxia* with special reference to Samoan plants, Professor Setchell says, "It is evident that the Polynesian species need much more study and comparison with types." I also have had difficulty

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in identifying many of the specimens collected by me with the descriptions of those previously found in Fiji. I have laid aside the doubtful plants for the present, but the two treated below are manifestly undescribed.

Alyxia erythrosperma Gillespie, species nova (fig. 20).

Frutex scandens; ramulis glabris, crassis, valde 4-angulatis canaliculatisque; foliis verticillatis, sessilibus, 9-13 cm. longis, 4-5 cm. latis, ellipticis ad oblongo-obovatis, apice obtusis et plerumque emarginatis; fructibus glabris, ellipsoideis, in siccitate valde 5-angulatis, 2.5-3.5 cm. longis, 1.5-1.8 cm. latis, haud moniliformibus; seminibus oblongo-ellipsoideis, circiter 18 mm. longis, 9 mm. latis; albumine ruminato, corneo, rubro.

A woody vine. Twigs glabrous, thick, stout, strongly 4-angled and deeply channeled, the ultimate ones 3-4 mm. thick, pale-brown, with large, scattered, brown lenticels; internodes 4-6 cm. long. Leaves verticillately whorled, usually 4 at a node, sessile, 9-13 cm. long, 4-5 cm. broad; blades glabrous, moderately thick, coriaceous, glossy above and beneath, elliptic to oblong-obovate, apex obtuse and usually notched, gradually narrowed to the broadly acute base, lateral nerves 20 to 30 on each side of the midrib, finely marked but distinct, spreading almost at right angles, in some specimens forked. Flowers unknown. Infructescences axillary, cymose, usually 5 or 6 fruits borne in a cluster, these often paired; pedicels scaly, thick, 6-7 mm. long; peduncles scaly, thick, 1-4 mm. long; bracts and bracteoles ovate, cuspidate, acute, scalelike, about 1 mm. long. Fruits smooth, glabrous, dull-green, ellipsoid, strongly 5-angled when dry, 2.5-3.5 cm. long, 1.5-1.8 cm. thick; seeds two, oblong-ellipsoid, 18 mm. long, 9 mm. broad; endosperm ruminate, horny, dull-red.

Fiji, Viti Levu, Namosi Province, at the edge of the trail between Nangarawai and Selenindrau villages, on the Wainikoroluva, altitude about 400 meters, October 1, 1927, John W. Gillespie. Type no. 3219.

Alyxia ovalifolia Gillespie, species nova (fig. 21).

Frutex scandens; ramulis glabris teretibus vel obscure angulatis; foliis verticillatis, olivaceis, nitidis, 5-7 cm. longis, 2.5-4 cm. latis, ellipticis ad obovato-ellipticis, apice rotundatis vel abrupte obtuseque acuminatis, basi obtusis ad late acutis, margine revoluto.

A woody vine. Twigs glabrous, moderately stout, pale-brown and with gray, raised lenticels, terete or obscurely angled, the ultimate branchlets about 2 mm. thick. Leaves verticillately whorled, usually 3 at a node, 5-7 cm. long, 2.5-4 cm. broad; blades glabrous, thick, coriaceous, dark-green or olivaceous, glossy above, dull beneath, elliptic to obovate-elliptic or oval, apex rounded and usually abruptly and obtusely acuminate, base obtuse to broadly acute, sometimes slightly decurrent, veins obscure beneath, visible above as very fine striations extending to the revolute margin, frequently forked and anastomosing; petioles rather stout, 9-13 mm. long. Flowers unknown. Infructescences axillary; cymose, usually about 8-fruited, these often paired; pedicels thick, about 3 mm. long; peduncles about 1 mm. long; bracts and bracteoles ovate, acute, scalelike, about 1 mm. long. Fruits (immature) smooth, glabrous, pale-green, ellipsoid to oblong, longitudinally angled when dry, 15-20 mm. long, 6-9 mm. broad, apiculate.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, in mossy woods at the summit of Loma Langa Mountain, altitude 1200 meters, December 19, 1927, John W. Gillespie. Type no. 4340.

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CARRUTHERSIA Seemann

Carruthersia latifolia Gillespie, species nova (fig. 22).

Frutex scandens subglaber; foliis junioribus subtus praesertim ad basin pilosis, mox glabris, chartaceis, 10-14 cm. longis, 7-9 cm. latis, late ovatis, apice breviter acuminatis, basi cordatis; petiolis 1.5-3 cm. longis, pilosis; inflorescentiis ad 12 cm. longis, quam foliis paullo longioribus; pedunculis 4-6 cm. longis; pedicellis 3-5 cm. longis; bracteis bracteolisque triangularis, ciliatis; floribus 2-3 cm. longis; calycis lobis ciliatis; corolla 2 cm. longa, tubo 10-12 mm. longo, intus hirsuto, lobis 9 mm. longis, subtriangularis; folliculis immaturis circiter 5 cm. longis, valde divaricatis, deorsum puberulis, teretibus, obtusis.

A stout vine, climbing to the tops of trees, subglabrous; twigs glabrous, smooth, terete, reddish-brown, often hollow. Young leaves lightly pilose beneath at the base and on the petioles, soon glabrous, bright-green, somewhat shining above, chartaceous, 10-14 cm. long, 7-9 cm. broad; blades broadly ovate to orbicular, apex shortly acuminate, base cordate, lateral nerves ascending, nearly straight, 7 to 9 on each side of the midrib, these and the veinlets obscure above but evident beneath; petioles stout, 1.5-3 cm. long. Inflorescences in the uppermost axils, up to 12 cm. long, the branches as much as 4 cm. long, spreading; peduncles 4-6 cm. long, rather stout; pedicels 3-5 mm. long; bracts and bacteoles broadly triangular, ciliate. Flowers fragrant, 2-3 cm. long; calyx about 2.5 mm. long and broad, lobes triangular, about 1 mm. long, ciliate; corolla tube 10-12 mm. long, hairy within and at the throat, lobes about 9 mm. long, asymmetric, subtriangular, conspicuously nerved; stamens about 3 mm. long; anthers elongate-sagittate, about 6 mm. long; filaments slender, lightly ciliate; style slender, about 2 mm. long; stigma clavate. Immature follicles 5 cm. long, 3 mm. thick, strongly divaricate, terete, elongate, gradually tapering to the obtuse apex.

Fiji, Taviuni, vicinity of Wairiki (northwest coast), edge of the woods above the coconut plantations, altitude about 400 meters, February 22, 1928, John W. Gillespie. Type no. 4656.

The fruits are described from Parks no. 20678, from Viti Levu, Tholo North Province, Nandarivatu. That specimens of this species were collected by Sir Everard im Thurn is indicated in a note by Turrill,[6] who considered this a form of *Carruthersia scandens* Seemann. The broader, chartaceous leaves, smaller flowers, and hairiness of the young leaves afford ample reasons for considering this a distinct species.

ALSTONIA R. Brown

Alstonia vitiensis Seemann (fig. 23).

Alstonia villosa Seemann: op. cit., p. 161, 1866, non Blume.
Alstonia vitiensis Seemann: Flora Vitiensis, p. 430, 1873.

"Foliis oppositis longe petiolatis ovalibus utrinque acutis, supra glabris, subtus villosis; floribus ignotis; folliculis longissimis cylindricis glabris.—Viti Levu (Seemann? no. 318)" Seemann. [As Seemann found the original name, *A. villosa*, to be preoccupied, he changed it to *A. vitiensis.*]

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[6] Turrill, W. B., A contribution to the flora of Fiji: Linnean Soc. London, Botany, Jour., vol. 43, p. 33, 1915.

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A tree, 12 meters tall; twigs stout, about 5 mm. thick at the extremities, glabrous. Leaves 30-40 cm. long, 15-20 cm. broad, but on young, unbranched shoots as much as 55 cm. long and 25 cm. broad, slightly resinous when young, at maturity coriaceous, bright, glossy-green and glabrous above, densely and velvety villous beneath, broadly elliptic to ovate, apex rounded, in some specimens retuse, base acute to acuminate, lateral nerves almost straight, slightly ascending, about 12 on each side of the midrib, impressed above; veinlets numerous, conspicuous above and beneath; petioles very stout, up to 8 cm. long. Inflorescences (Gillespie no. 3653) many-flowered, erect, open, compound-corymbose, the main axis rather stout, sometimes as much as 15 cm. to the first branches which are spreading, the lower ones up to 14 cm. long; pedicels 2-4 mm. long, slender. Flowers pale-yellow to white; calyx glabrous, about 2 mm. long, 1.8 mm. in diameter, lobes about 1 mm. long, subtriangular, rounded, entire; corolla about 11 mm. long, tube glabrous without, about 5 mm. long, enlarged at the middle, lobes about 6 mm. long, 1.2 mm. broad, broadly spreading, strap-shaped, gradually tapering to the rounded apex, faintly marked with parallel veins, the throat and the base of the lobes covered with coarse, whitish hairs; ovary about 1 mm. long, 0.5 mm. thick, ovoid; style about 0.8 mm. long, slender; stigma about 0.8 mm. long, ciliate, conic, the disc at the base evident; anthers about 1 mm. long, acuminate; filaments very short, slender. Fruits numerous; peduncles thick, tough, fibrous; calyx-lobes persistent; follicles about 30 cm. long, 3 mm. thick, longitudinally striate, gradually tapering to an acute or often truncate apex. Seeds about 15 mm. long, linear, glabrous; body about 4 mm. long, 1 mm. broad, attenuate at each end, margin strongly ciliate.

Represented by Gillespie nos. 2467, 3623, and 3653, all from the vicinity of Suva. The tree is called "wild rubber," on account of the abundant milky sap which becomes gummy on exposure to air. Native name: *sa rou ia.*

TABERNAEMONTANA Plumier

Tabernaemontana thurstoni Horne ex Baker (fig. 24).

Tabernaemontana thurstoni Horne ex Baker: Linnean Soc. London, Botany, Jour., vol. 20, p. 368, 1883; Kew Bull., p. 164, 1898.—Burkill, Linnean Soc. London, Botany, Jour., vol. 25, p. 46, 1901.

"Arborea, glabra, foliis petiolatis oblongis magnis subcoriaceis, cymis axillaribus paucifloris quam folia duplo breviores, pedicellis elongatis, calycis pilosi tubo campanulato, segmentis semiorbicularibus, folliculis patulis glabris inaequilateraliter ovoideis."—*Baker.*

A large, glabrous tree, with grayish bark and wrinkled twigs. Leaves 15-22 cm. long, 4-9 cm. broad, chartaceous, elliptic to oblong-elliptic or obovate, apex obtusely acuminate, rounded, base acute, often slightly decurrent; petioles 4-10 mm. long; stipules broad, rounded, connate, about 3 mm. long, conspicuous on young twigs. Inflorescences terminal, about 9 cm. long, few-flowered; peduncles about 4 cm. long; pedicels about 2 cm. long; calyx about 3 mm. long, lobes rounded; corolla about 5 cm. long, white, fleshy, and gelatinous, tube about 2 cm. long, 3 mm. in diameter at the base, enlarged upwards, lobes oblong, falcate; fruiting peduncles 2-3 cm. long, stout, calyx persistent; pods strongly recurved, the tips of each pair often touching, 3-5 cm. long, 2.5 cm. thick, crescent-shaped, rough and warty, valves gaping when dry; seeds reddish, about 13 mm. long, ellipsoid.

The trees have a spreading crown and dense foliage, and the leaves emit a mouselike odor when drying. Flowers fragrant but seldom seen; I believe

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that the corollas fall at night. A species originally described in the absence of flowers and mature fruits, of which even Burkill's redescription fails to give the complete characters of the flowers and the measurements of the mature fruits. Represented by Gillespie nos. 3557, 4128, 4296, 4788, and 4809, from Viti Levu and Taviuni.

GESNERIACEAE

CYRTANDRA Forster

Plants of the genus *Cyrtandra* are rather common as undershrubs in the forests of Fiji; yet they are seldom conspicuous. The flowers of most species are few, borne either on the older twigs and trunks or else partially concealed among the leaves; they are of a yellow, greenish, or cream color which renders them difficult to detect. Both leaves and flowers of many species are fleshy or gelatinous in texture, and special care is required to prepare good material. Both Parks and I collected them assiduously in the areas where we worked, and by preserving the flowers and fruits in alcohol, we obtained material fairly satisfactory for study. I have compared specimens in the Parks-Gillespie collection with the revised descriptions of Fijian species given by Clarke[7] in his monograph on Cyrtandreae and I find ten species which presumably have not been described previously. There is other material that is inadequate for satisfactory identification or description.

Cyrtandra (§ Polynesieae) alba Gillespie, species nova (fig. 25).

Arbor parva, glabra; foliis 14-20 cm. longis, 4-7 cm. latis, tenuiter chartaceis, ellipticis ad ovatis, apice breviter acuminatis, basi acutis ad acuminatis; fasciculis 1-3-floris, e caulis ramisque vetustioribus; floribus 4-5 cm. longis; pedicellis circiter 1 cm. longis; calycibus deciduis, circiter 1 cm. longis, lobis brevissimis, triangularis; corolla membranacea, circiter 3 mm. longa.

A small tree, glabrous throughout. Twigs moderately stout, soft and fleshy at the extremities. Leaves 14-20 cm. long, 4-7 cm. broad; blades green above, paler beneath, rather thin, chartaceous, elliptic to ovate, apex shortly acuminate, somewhat cuneate toward the acute or acuminate base, margin subentire or in some leaves decidedly crenate, lateral nerves ascending, about 9 on each side of the midrib, veinlets few but distinct; petioles slender, up to 5 cm. long. Cymes 1-3-flowered, from older wood. Flowers 4-5 cm. long, pendent; pedicels about 1 cm. long; peduncles practically none; calyx deciduous, about 1 cm. long, lobes very short, triangular; corolla white, membranaceous, distinctly nerved, about 3 cm. long or even longer, slightly curved, lobes about 5 mm. long, broadly ovate; style exserted. Fruits immature.

Fiji, Viti Levu, Namosi Province, in dense woods on the upper slopes of Voma Mountain, altitude 800 meters, September 6, 1927, John W. Gillespie. Type no. 2671. Native name: *me ndiri tambua.* Gillespie no. 2924, the same species, is from Voma Mountain at a lower elevation.

[7] Clarke, C. B., Cyrtandreae, in DeCandolle's Monographiae phanerogamarum, vol. 5, pp. 1-304, 1883.

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Cyrtandra (§ Aureae) cephalophora Gillespie, species nova (fig. 26).

Frutex subglaber, partibus junioribus adpresso-puberulis; foliis 18-23 cm. longis, 6-8 cm. latis, crassis, carnosis, fragilibus, ellipticis, apice acutis, basi acutis ad obtusis; cymis capitatis; floribus numerosis, confertis; capitulis circiter 2 cm. longis; pedunculis crassis, ad 1.5 cm. longis, bracteis numerosis imbricatis brevibus ferentibus; bracteis floriferis foliaceis, perspicuis, confertis, extus glabris, intus nigro-pilosis; floribus circiter 1 cm. longis; calycibus deciduis.

A glabrous shrub. Twigs thick, stout, brown, 4-angled at the extremities, bark papery, pith large. Leaves 18-23 cm. long, 6-8 cm. broad; blade somewhat thick, fleshy, brittle, elliptic to oblong-elliptic or obovate, apex acute, base acute to obtuse, margin crenate-serrate, teeth in many specimens obscure, lateral nerves strongly ascending, 6 to 9 on each side of the midrib, veinlets few and obscure, evident above and beneath; petioles stout, flattened and grooved, 3-4 cm. long. Cymes axillary, capitate, the numerous flowers in a dense cluster about 2 cm. long; peduncles stout, up to 1.5 cm. long, bearing numerous, imbricated bracts; flower-bracts very conspicuous, thickly crowded on the axis, foliaceous, ovate, acute, blackish-pilose within, glabrous without. Flowers about 10 mm. long; calyx deciduous, about 8 mm. long, glabrous except the base which bears a few black hairs, lobes about 3 mm. long, acuminate; corolla broadly campanulate, 8 mm. long, lobes ovate, membranaceous, about 8 mm. long. Immature fruits ovoid, orange-colored, apiculate, about 7 mm. long.

Fiji, Viti Levu, Namosi Province. in dense woods just below the summit of Naitarandamu Mountain, altitude 1200 meters, September, 1927, John W. Gillespie. Type no. 3121. Gillespie no. 2416, representing the same species, came from Naitasiri Province, woods of Tamavua, seven and one-half miles from Suva.

Cyrtandra (§ Polynesieae) gracilipes Gillespie, species nova (fig. 27).

Frutex erectus, glaber; ramulis gracilibus; foliis 18 cm. longis, 2-3.5 cm. latis, tenuiter chartaceis ad membranaceis; apice acutis ad acuminatis, basi acuminatis; margine remote repando-serrato; cymis paucifloris, e caulis ramisque vetustioribus; floribus solitariis vel binis, 2-2.5 cm. longis; pedicellis gracilibus; calycibus deciduis, 8 mm. longis, lobis 5, acuminatis, patulis; corolla 15 mm. longa.

A glabrous shrub. Twigs rather slender, pale-brown. Leaves 8-18 cm. long, 2-3.5 cm. broad; blades green on both sides, thinly chartaceous or even membranaceous, elongate-elliptic, apex for the most part acute to acuminate but in some specimens rounded or even retuse, base acuminate, margin irregularly and distantly repand-serrate, especially toward the apical part, lateral nerves ascending, about 5 on each side of the midrib, obscure above but distinct beneath, veinlets obscure; petioles slender, 1-2 cm. long. Cymes mostly from leafless twigs and older wood. Flowers solitary or in pairs, 2-2.5 cm. long; pedicels slender, about 1 cm. long, each bearing at the base 2 narrow, subulate, deciduous bracts; peduncles about 1 cm. long; calyx about 8 mm. long, deciduous, lobes 5, acuminate, spreading, 2-3 mm. long; corolla white, 15 mm. long, tube cylindric, slightly curved, lobes 4-5 mm. long, broadly ovate, strongly reflexed when fully open; pistil about 8 mm. long. Fruits about 15 mm. long, ovoid, apex flattened or even depressed, base more or less truncate; disc absent.

Fiji, Viti Levu, Rewa Province, in dense woods on the southeast slopes of Korombamba Mountain, altitude 300 meters, August 17, 1927, John W. Gillespie. Type no. 2306.

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Cyrtandra (§ Campanulaceae) glandulosa Gillespie, species nova (fig. 28).

Frutex; ramulis foliisque junioribus dense hirsutis, pilis multiseptatis; foliis usque ad 50 cm. longis et 20 cm.. latis, utrinque hirsutis, crassis, coriaceis, acutis, basi rotundis, nervis primariis utrinque circiter 12, subtus valde perspicuis; cymis densis, subsessilibus, plurifloris, pedunculis pedicellisque 10 mm. longis, bracteis foliaceis, 20 mm. longis, 12 mm. latis, extus pilis paucis capitato-glandulosis ferentibus; floribus 3 cm. longis; calycibus fructiferis persistentibus, extus glanduloso-hirsutis.

A shrub; young parts covered with a dense, velvety coat of golden to brown or black, multiseptate hairs. Twigs of the main axis stout, those of the lateral branches more slender and curved, almost scandent, obscurely and obtusely 4-angled, ultimate ones about 5 mm. in diameter. Leaves variable in size, the largest 50 cm. long and 20 cm. broad; blades hirsute on both sides, dark-green above, much paler and somewhat golden beneath, thick, coriaceous, broadly ovate, apex acute to shortly acuminate, base rounded, margin distantly and minutely serrate, ciliate, densely hairy beneath, lateral nerves about 12 on each side of the stout midrib, these and the reticulate veins impressed on the upper surface, and both very conspicuous beneath; petioles stout, base somewhat thickened, up to 9 cm. long, densely hirsute. Cymes very dense, many-flowered, subsessile, in the uppermost axils; peduncles stout, about 1 cm. long, equal to the pedicels; bracts numerous, foliaceous, about 20 mm. long, 12 mm. broad, ovate, acute, glabrous within, lightly covered on the outside with glandular-capitate hairs; flowers about 3 cm. long; calyx persistent, about 2.4 cm. long, glandular-hairy on the outside, glabrous within, saccate, completely enclosing the fruit at maturity, lobes 3 mm. long, triangular; corolla pale-yellow, tube narrowly cylindric, sparsely hairy near and on the lobes which are ovate and 4 mm. long. Fruits ovoid, 18 mm. long, apiculate.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, valley of the Singatoka River, on the side towards Loma Langa Mountain, altitude 875 meters, November 17, 1927, John W. Gillespie. Type no. 3852. An unbranched shrub 2 meters high. The leaves shrank enormously in drying. Native name: *mbeta levu.*

Cyrtandra (§ Polynesieae) montana Gillespie, species nova (fig. 29).

Frutex erectus, corolla intus furfuracea excepta glaber; foliis 9-12 cm. longis, 2-3 cm. latis, oblongo-ellipticis ad oblongo-lanceolatis, apice acuminatis, basi acutis; cymis laxis paucifloris; pedunculis pedicellisque gracillimis, circiter 4 cm. longis; bracteis deciduis, 2-4 mm. longis, subulatis ad oblanceolatis; floribus 16 mm. longis; calycibus deciduis, membranaceis, apertis, 8 mm. longis; corolla circiter 1 cm. longa, late infundibuliforme.

A shrub, glabrous except the inside of the corolla. Twigs stout, wrinkled when dry, bark papery. Leaves 9-12 cm. long, 2-3 cm. broad; blades bright-green above, dull beneath, chartaceous, oblong-elliptic to oblong-lanceolate, apex acuminate, tip obtuse, base acute, margin lightly dentate-crenate, lateral nerves gradually ascending, about 7 on each side of the midrib, veinlets few, obscure above but very distinct beneath; petioles 4-5 mm. long. Cymes lax, few-flowered; peduncles and pedicels very slender, the peduncles about 2 cm. long, the pedicels usually shorter; bracts herbaceous, 2-4 mm. long, subulate to oblanceolate, deciduous. Flowers about 16 mm. long; calyx deciduous, membranaceous, spreading, about 8 mm. long, lobes glabrous, about one-half united, ovate-triangular, apiculate; corolla white, broadly funnel-shaped, about 1 cm. long, inside conspicuously furfuraceous, glabrous without, lobes ovate, somewhat acute or even apiculate, faintly marked with about 7 longitudinal nerves. Fruits ovoid, apiculate, about 8 mm. long; disc annular.

Fiji, Viti Levu, Namosi Province, wooded ridge on Naitarandamu Mountain, altitude 1100 meters, September 28, 1927, John W. Gillespie. Type no. 3144.

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Cyrtandra (§ Polynesieae) monticola Gillespie, species nova (fig. 30).

Frutex erectus; ramulis ultimis ferrugineo-tomentosis, glabrescentibus; foliis 12-15 cm. longis, 3-4 cm. latis, leviter puberulis, oblongo-ellipticis ad oblongo-lanceolatis, apice acutis ad leviter acuminatis, base rotundatis ad late acutis, haud acuminatis; cymis 1-3-floris; pedicellis ad 10 mm. longis; pedunculis circiter 2.5 cm. longis, bracteis subnaviculàribus, 15 mm. latis, basi connatis, foliaceis, persistentibus, acutis, intus in partibus inferioribus hirsutis.

A shrub. Twigs at the extremities ferruginous-tomentose, glabrescent, moderately stout, obscurely and obtusely 4-angled, longitudinally ridged. Leaves 12-15 cm. long, 3-4 cm. broad; blades dark-green and entirely glabrous above, paler beneath, densely tomentose when young, at maturity slightly puberulent, oblong-elliptic to oblong-lanceolate, apex acute to somewhat acuminate, base rounded, in some specimens slightly acute but not at all acuminate, margin minutely serrate, ciliate, lateral nerves 5 or 6 on each side of the midrib, strongly ascending, veinlets obscure; petioles puberulent, fairly stout, up to 2 cm. long. Cymes 1-3-flowered; pedicels about 10 mm. long, exserted from bracts; peduncles 2.5 cm. long, stout; bracts boat-shaped, 15 mm. long, 10 mm. broad, foliaceous, connate below, persistent, acute, hairy within on the lower parts, ciliate, obscurely veined. Flowers incomplete in specimens collected by me; calyx deciduous, about 11 mm. long, outside hairy, glabrous within, lobes equal, about 3 mm. long, spreading. Fruits ovoid, acute, apiculate, disc annular, pubescent, lower portions of the calyx persisting at the base of the fruit.

Fiji, Viti Levu, Namosi Province, wooded ridges near the summit of Naitarandamu Mountain, altitude 1100 meters, September 27, 1927, John W. Gillespie. Type no. 3122. This species has the type of inflorescence of *C. involucrata* Seemann, but differs markedly in the shape of the leaves.

Cyrtandra (§ Campanulaceae) multiseptata Gillespie, species nova (fig. 31).

Frutex erectus; ramulis junioribus dense pilosis; pilis multiseptatis, mox glabrescentibus; foliis subtus ad costam nervosque persistente pilosis, 20-30 cm. longis, 7-10 cm. latis, apice obtusis ad leviter acuminatis, basi acutis; petiolo 4-6 cm. longo; cymis dense pilosis, 1-3-floris; pedunculis pedicellisque usque ad 5 mm. longis; calycibus persistentibus fructibus integentibus, extus dense pilosis, 3.5 cm. longis; fructibus elongatis.

A shrub, 2 meters high (Parks). Twigs pilose at the extremities with castaneous to black, multiseptate hairs, the older parts glabrous, thick, light-brown, obscurely and obtusely 4-angled, pith large. Leaves in unequal pairs, 20-30 cm. long, 7-10 cm. broad; juvenile blades densely pilose with castaneous to black, multiseptate hairs some of which are 3 mm. long, later becoming nearly glabrous above but retaining the hairs on the midrib, nerves, and veins beneath, at maturity dark-green above, paler beneath, chartaceous, elliptic to obovate, apex obtuse to slightly acuminate, base acute and somewhat decurrent, margin lightly and irregularly repand-serrate, ciliate, lateral nerves ascending, 9 to 12 on each side of the midrib, united by anastomosing veinlets forming subrectangular blocks, rather conspicuous beneath; petioles densely pilose with brown hairs, slender, deeply grooved, flattened or even winged, 4-6 cm. long. Cymes densely hairy, 1-3-flowered, peduncles less than 5 mm. long, equal to the pedicels; bracts deciduous, about 3 mm. long. Flowers unknown; fruiting calyx persistent, obscurely 2-lobed, on the outside densely pilose with brown, multiseptate hairs, sparingly hairy within, up to 3 cm. long, elongate, subcylindric, lobes approximately equal, acuminate, about 10 mm. long. Fruits ellipsoid, elongate, dull-black, glabrous, about 25 cm. long, 8 mm. thick, completely enclosed by the calyx.

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Fiji, Viti Levu, Namosi Province, in wet canyons in the vicinity of Namosi village, altitude 800 meters, July, 1927, H. E. Parks. Type no. 20327.

In fruit shape this species is like *Cyrtandra utriculosa* C. B. Clarke, but *C. multiseptata* has a shorter calyx and long acuminate lobes, and the hairs on the young parts are multiseptate. From this last character the specific name of the plant is derived.

Cyrtandra (§ Polynesieae) prattii Gillespie, species nova (fig. 32).

Frutex erectus; foliis 16-22 cm. longis, 5-8 cm. latis; junioribus puberulis mox glabrescentibus, oblongis ad oblongo-ellipticis, apice acuminatis, basi obtusis ad acutis; cymis caulinis, pubescentibus; pedunculis crassis, ramulis similimis, simplicibus vel saepe furcatis, usque ad 40 cm. longis; floribus circiter 2.5 cm. longis, luteis; calycibus deciduis, circiter 1.8 mm. longis, extus pubescentibus.

A shrub, juvenile parts pubescent, soon becoming glabrous. Twigs rather stout, gray or light-brown, obscurely and obtusely 4-angled. Leaves in unequal pairs, 16-22 cm. long, 5-8 cm. broad, shrinking in drying; blades dark-green and glabrous above, yellowish beneath, thick, puberulent when young, soon glabrescent, chartaceous, oblong-elliptic, apex acuminate, base obtuse to acute or even decurrent, margin finely and irregularly serrate, lateral nerves 8 to 10 on each side of the midrib, sharply ascending, nearly straight, these joined by anastomosing veinlets, evident above and beneath; petioles rather stout, flattened, or, in some, slightly winged, 1.5-3 cm. long. Cymes pubescent; flowers single in the axils of bracts, clustered near the extremities of the stout, branch-like peduncles which are borne on the trunk, frequently forked, somewhat pendent, and marked at short intervals by bract-scars; bracts about 8 mm. long, 3 mm. broad, oval, chartaceous, pubescent without, especially on the midvein; pedicels about 4 mm. long. Flowers about 2.5 cm. long, curved; corolla yellow, about 1.8 cm. long, 7 mm. broad at the throat, outside covered thinly with tawny hairs, glabrous within, lobes short, oval; calyx deciduous, about 18 mm. long, lobes acute, the upper ones about 7 mm. long, forming a sort of hood, the lower ones shorter, downward curved, pubescent without, slightly hairy within; stamens included. Fruits glabrous, soft, ovoid, about 14 mm. long, 5 mm. thick, apiculate by the persistent style; disc evident, pubescent, about 3 mm. in diameter.

Fiji, Viti Levu, Tholo North Province, in thick woods near the summit of Mount Victoria (Tama ni ivi), altitude 1250 meters, November 28, 1927, John W. Gillespie. Type no. 4091.

This species is named in honor of John Robert Pratt, of the Fiji Kauri Timber and Land Company, whose keen eye and ready axe were the means of bringing many fine specimens into my hands.

Cyrtandra (§ Polynesieae) taviunensis Gillespie, species nova (fig. 33).

Frutex erectus, glaberrimus; nodis superioribus leviter incrassatis, internodis circiter 1 cm. longis; foliis 18-23 cm. longis, 3.5-5 cm. latis, oblongis ad oblongo-lanceolatis, utrinque acuminatis; cymis 1-3-floris, ad 13 cm. longis, pedunculis pedicellisque gracillimis, bracteis 3 ad 5 paribus, subpersistentibus, 10-15 mm. longis, 3-4 mm. latis; floribus 20 mm. longis, longe pedicellatis; calycibus deciduis; corolla 15 mm. longa; fructibus subellipsoideis, 17 mm. longis.

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A glabrous shrub. Twigs moderately stout, obscurely and obtusely 4-angled, wrinkled when dry, nodes near the extremities somewhat enlarged, internodes about 1 cm. long, leaves 18-23 cm. long, 3.5-5 cm. broad; blades dark-green above, yellowish beneath, chartaceous, oblong to oblong-lanceolate, acuminate at each end, margin slightly repand-crenate, especially toward the apex, lateral nerves curved, ascending, about 6 on each side of the midrib, veinlets few but conspicuous beneath, obscure above; petioles flattened, 1-1.5 cm. long. Cymes 1-3-flowered, up to 13 cm. long; peduncles and pedicels very slender, varying in length but usually about equal to each other; bracts herbaceous, subpersistent, 3 to 5 pairs, 10-15 mm. long, about 4 mm. broad, with 1 to 3 longitudinal veins. Flowers 20 mm. long; calyx deciduous, 13 mm. long, usually splitting into 3 lobes which are about 7 mm. long, acuminate, often reflexed; corolla pale, cream-colored, about 15 mm. long, tube cylindric, lobes broadly spreading, often reflexed, oval, densely papillate within. Fruits abundant, red, subellipsoid, about 17 mm. long, slightly apiculate; disc annular.

Fiji, Taviuni, in moist, steep-sided ravines on mountains inland from Somo-somo village, altitude 850 meters, March 5, 1928, John W. Gillespie. Type no. 4782. This is a very common and beautiful shrub, its dark-green leaves and bright-red fruits forming a most pleasing contrast.

Cyrtandra (§ Campanulaceae) victoriae Gillespie, species nova (fig. 34).

Frutex vel arbor parva, ramulis foliisque junioribus dense hirsutis, pilis aureis, multiseptatis; foliis subtus ad costam nervosque persistente hirsutis, crassis, carnosis, ellipticis, utrinque acutis; cymis 1-3-floris; pedunculo circiter 1 cm. longo, quam pedicellis longioribus; calycibus persistentibus coriaceis, 3.5 cm. longis, lobis 3-4, inequalibus, acutis, superioribus circiter 1 cm. longis, ad apicem plus minusve connatis, inferioribus paullo brevioribus; corolla 3 cm. longa; fructibus subglobosis, recurvatis.

A shrub or small tree. Juvenile parts densely hirsute with golden to brown, multiseptate hairs; older twigs glabrous, very thick, obscurely and obtusely 4-angled, pale-brown, wrinkled in drying, bark papery, pith large. Leaves opposite, in unequal pairs, 35-44 cm. long, 10-14 cm. broad; when young densely covered on both sides with golden-velvety hairs, later becoming scurfy-pilose on the upper side, persistently and densely hairy beneath, especially on the lateral nerves and veins; blades thick, heavy, rigid and brittle when fresh, yellowish-green, elliptic to broadly elliptic, apex and base acute, margin finely dentate-serrate, the teeth densely ciliate with tufted hairs, lateral nerves 8 to 10 on each side of the midrib, strongly ascending, these and the narrow anastomosing veinlets obscure above but conspicuous beneath; petioles stout, densely hairy, up to 6 cm. long. Cymes axillary, densely hairy, 1-3-flowered; peduncles about 1 cm. long, thick, longer than the pedicels; bracts caducous. Flowers odorless, about 4 cm. long, curved, fleshy; calyx persistent, coriaceous, curved, hairy on the outside, glabrous within, 3-5 cm. long, splitting into 3 or 4 unequal, acute lobes, the upper two 1 cm. long, their tips often joined, forming a sort of hood, the lower ones shorter, downward curved; corolla 3 cm. long, white, tubular to funnel-shaped, hairy on the outside above the middle, throat glabrous, tube lightly ciliate within, lobes practically equal, 3 mm. long, oval; stamens included, about 12 mm. long; anthers broadly ovoid, united; filaments curved; pistil 18 mm. long; stigma discoid. Fruits glabrescent, ovoid to subglobose, about 15 mm. long, 10 mm. in diameter, apiculate by the persistent style, hard, dry, their tips protruding from the calyces.

Fiji, Viti Levu, Tholo North Province, in dense woods at the summit of Mount Victoria (Tama ni ivi), altitude 1250 meters, November 29, 1927, John W. Gillespie. Type no. 4088. Other collections are represented by Parks no. 20129, on Korombamba Mountain, Rewa Province; Gillespie no.

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4349, at the summit of Loma Langa Mountain, Tholo North Province; Gillespie no. 3263, near the summit of Vakarongasiu Mountain, Namosi Province. The leaves shrank enormously in drying.

RUBIACEAE

OPHIORRHIZA Linnaeus

Ophiorrhiza peploides A. Gray (fig. 35 *a, b, c*).

Ophiorrhiza peploides A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 311, 1860.

"Herbacea, pumila, diffuse ramosa; ramis puberulis foliolosis; foliis parvis saepe 3-5-natis vel pseudo-verticillatis spathulatis seu ovato-sphathulatis basi longe attenuatis glabris; floribus subsolitariis glabris; filamentis filiformibus styloque exsertis.—Feejee Islands."—A. Gray.

The leaves rarely exceed 2 cm. in length. The flowers are about 11 mm. long; calyx about 1.5 mm. long, the lobes very short, acute; corolla-tube about 5 mm. long, expanded at the throat, lobes about 4 mm. long, oblong, acute, lepidote within, glabrous without. Fruits about 3 mm. long, strongly compressed, about 6 mm. broad, sparsely puberulent, apex broadly and shallowly retuse.

Represented by Gillespie nos. 2618, 2706, 3589, 4061, 4400.1, 4462, 4577, and 4680. Native names: *le ra; ndi-ndi-ndi.*

Ophiorrhiza leptantha A. Gray (fig. 35, *d, e, f*).

Ophiorrhiza leptantha A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 312, 1860.

Ophiorrhiza laxa A. Gray: op. cit.

"Fruticosa, fere glabra; foliis laetevirentibus oblongoseu elongato-lanceolatis utrinque acuminatis longe petiolatis; stipulis utrinque binis setaceis; cyma multiflora puberula; floribus plerisque secundis subsessilibus; corolla alba gracili pollicari, ore tenuissime barbato; staminibus inclusis; filamentis anthera aequilongis; stylo glabro. Feejee Islands."—A. Gray.

In characterizing the two species *Ophiorrhiza leptantha* and *O. laxa,* Asa Gray remarked that they were perhaps confluent. Seemann lists both species, citing one number in his collection for each. Gibbs (Linnean Soc., London, Botany, Jour., vol. 39, p. 151, 1915) states that one species runs into the other, but Turrill (Linnean Soc. London, Botany, Jour., vol. 43, p. 24, 1909), judging from specimens collected by Sir Everard im Thurn, thinks they are quite different.

On examination of an ample suite of 76 specimens from Viti Levu, Ovalau, and Taviuni, I am unable to distinguish the two supposed species. Some plants are entirely glabrous, and others are markedly puberulent, especially on the young parts. The margin of the leaf is often ciliate, with multiseptate,

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bristly hairs. The leaves are usually 7-11 cm. long, 2-4 cm. broad; the petioles are up to 3 cm. long. On one specimen, collected in deep shade near the summit of Naitarandamu Mountain, the leaves are as much as 15 cm. long and 5 cm. broad, but the flowers are almost identical with those of smaller leaved forms from lower elevations. The fruits are strongly compressed, about 7 mm. broad. In the absence of characters of constancy and importance, I regard them all as a single species.

Represented by Parks nos. 20535, 20583, and 20926; Gillespie nos. 2014, 2046, 2159, 2229, 2247, 2439, 2440, 2481, 2684, 2685, 2987, 3122, 3294, 3295, 3690, 4090, 4361, and 4430. Native names: ***ndrai ni kau ni mbata, ndrai ni kau ni ula, mothi-mothi.*** The name ***mothi-mothi,*** which means "go to sleep," is applied to any plant which folds its leaves at night; it would seem to be without significance in this species.

DOLICHOLOBIUM A. Gray

Dolicholobium macgregori Horne ex Baker (fig. 36).

Dolicholobium magregori Horne ex Baker: Linnean Soc. London, Botany, Jour., vol. 20, p. 360, 1884.

"Arborea, glabra, ramulis validis tetragonis, stipulis magnis oblongis foliaceis persistentibus, foliis breviter petiolatis magnis obovato-oblongis, floribus, 3-4 nis axillaribus racemosis magnis albis suaveolentibus, ovario longissimo cylindrico, calycis limbo magno patellaeformi."—BAKER. Type locality: Banks of the Tamavua river, near Suva, Viti Levu, Horne no. 690.

A medium-sized tree, with very thick rough twigs which are obscurely 4-sided when young; leaf scars prominent. Leaves 23-40 cm. long, 12-20 cm. broad; blades often glabrous, subcoriaceous, bright-green and shining above, paler beneath, the nerves often appressed-pubescent especially when young, broadly obovate to elliptic, apex rounded to very broadly acuminate, base (generally concealed by the stipules) rounded, lateral nerves prominent, 14 to 17 on each side of the midrib, about 17 mm. apart, slightly curved, ascending, extending to the very margin, connecting veins very numerous, subprominent, perpendicular to the laterals; stipules foliaceous, persistent, obovate, apex rounded, longitudinally lineate, verrucose near the base, as much as 8 cm. long and 4 cm. broad; petioles very stout, about 2 cm. long. Inflorescences axillary, generally 3- to 5-flowered; peduncles about 3 cm. long; pedicels short, ascending; flowers white, very fragrant; calyx-tube cylindric, narrow, pubescent, about 2.5 cm. long, limb patelliform, about 8 mm. long, 10 mm. in diameter, the margin ciliate with tawny hairs; corolla-tube narrowly funnel-shaped, appressed-pubescent with tawny hairs, 3-4 cm. long, lobes spreading, as much as 2.5 cm. long, 1.5 cm. broad, obovate, rounded, lineate. Fruiting peduncles stout, about 5 cm. long; fruits glabrescent, cylindric, striate, as much as 35 cm. long, 7 mm. thick, apex truncate or crowned by the calyx-limb which may become 2 cm. in diameter; seeds pale-brown, scarcely 1 mm. broad, each end long-caudate, about 10 mm. long.

Represented by Parks nos. 20127, 20284, and 20896; Gillespie nos. 2297, 2368, all from Viti Levu, in the vicinity of Suva. The ovary enlarges very rapidly after fertilization, and the fruits, after hanging for some time, become shreddy, releasing the small seeds in great numbers. Native name: ***so so ni oora.*** Parks no. 20896 furnished the subject for figure 36.

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BADUSA A. Gray

The characters of the genus *Badusa* are given by Gray (Am. Acad. Arts and Sci., Proc., vol. 4, p. 308, 1860) as follows:

Calyx tubo clavato; limbo brevi cupulato 5-dentato persistente. Corolla hypocraterimorpha, glabra, 5-fida; limbo tubum adaequante, lobis lineari-oblongis aestivatione contorto-imbricatis (uno exteriore), explicatis patenti-recurvis. Stamina 5, exserta: filamenta filiformia, imae basi corollae inserta, inferne villosa; antherae lineares, dorso supra basim affixae, mox versatiles. Stylus filiformis, ramis 2 brevibus cum stigmatibus subcapitatis intus planis in clavellam angulatam conglutinatis. Ovarium biloculare. Ovula in placentis lineari-oblongis crassis plurima, anatropa, sese imbricantia, superiora adscendentia, inferiora pendula. Capsula clavato-oblonga, cartilaginea, bilocularis, polysperma, ab apice ad basim septicida. Semina ovalia, modice lata. Embryo rectus albumine carnoso paullo brevior; radicula tereti cotyledonibus ovatis longiore. Fructices sempervirentes? Oceanici, glabri; stipulis brevibus vaginatis; pedunculis axillaribus apice foliatis cymoso-plurifloris; floribus albis.

Badusa corymbifera A. Gray (fig. 37).

Badusa corymbifera A. Gray: op. cit.

A slim tree, with short, slender branches, glabrous except the flowers. Leaves as much as 13 cm. long, 4 cm. broad; blades shining, thin-chartaceous or submembranaceous, often yellowish when dry, oblong to elliptic-lanceolate, apex obtuse, rounded, base acute to acuminate, lateral nerves 7 to 9 on each side of the midrib, obscure above, very prominent beneath, veins indistinct; petioles about 1 cm. long. Inflorescences axillary, erect, up to 6 cm. long, about 15-flowered; peduncles stout, often 4 cm. to the first branches; pedicels about 5 mm. long; flowers rather conspicuous; calyx about 6 mm. long; ovary narrow; limb truncate or obscurely toothed, about 2 mm. in diameter, margin ciliate; corolla about 12 mm. long; stamens often 5 mm. long. Fruits 1 cm. long, becoming shreddy.

Represented by Parks no. 20035; Gillespie nos. 4261 and 4611, all from Viti Levu, in the woods near Suva Harbor, in limestone soil.

NEONAUCLEA Merrill

Neonauclea vitiensis Gillespie, species nova (fig. 38).

Arbor, ramulis junioribus pilosis glabrescentibus; foliis 14-20 cm. longis, 9-12 cm. latis, coriaceis, late ellipticis ad obovatis, apice obtusis, basi rotundis, interdum obscure cordatis; stipulis ovatis, obtusis, 15-18 mm. longis, 10 mm. latis, basi pilosis; inflorescentiis solitariis, terminalibus; pedunculis 2-5 cm. longis; calycibus 7-8 mm. longis, pubescentibus, lobis 6 mm. longis, clavatis, deciduis; corolla 10-12 mm. longa, lobis leviter ciliatis exceptis glabra; stylis longe exsertis.

A nearly glabrous tree. Twigs glabrous, thick, stout, rough, young parts grayish pilose, obscurely 4-angled, flattened, brownish, marked with horizontal striations, leaf-scars round. Leaves 14-20 cm. long, 9-12 cm. broad; blades thick, coriaceous, light-green above and beneath, broadly elliptic to obovate, apex broadly obtuse, base rounded or sometimes cordate, often slightly inequilateral, entire, lateral nerves about 5 on each side of the midrib, veinlets obscure above but distinct beneath; petioles stout, 2-4 cm. long; stipules intrapetiolar, caducous, ovate, obtuse, 15-18 mm. long, about 10 mm. broad, pilose near the base. Inflorescences solitary, terminal, forming a compact, globose head,

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5 cm. in diameter including the tips of the long styles; peduncles 2-5 cm. long; calyx 7-8 mm. long, grayish pubescent within and without, lobes about 6 mm. long, clavate, deciduous; corolla dark-red, 10-12 mm. long, 2.3 mm. broad at the throat, narrow, tubular, nearly glabrous, lobes about 15 mm. long, lightly ciliate; anthers oblong, about 1.5 mm. long, included; filaments about 0.3 mm. long, flattened, affixed rather high in the corolla-tube; pistil about 17 mm. long; style long exserted; stigma clavate. Receptacle globose, gray-pubescent, about 12 mm. in diameter.

Fiji, Viti Levu, Tholo North Province, steep slopes of the canyon of the Mata ni Wasi, northeast of the Government Station, Nandarivatu, altitude 750 meters, December 4, 1927, John W. Gillespie. Type no. 4188. Several large trees with trunks up to 45 cm. in diameter were found, and the specimens were taken from a tree which overhung the trail. *Geniostoma rupestre, Dodonaea viscosa, Alphitonia excelsa, Scaevola floribunda, Metrosideros* sp., and other plants characteristic of the leeward slopes of Viti Levu were growing near by. Native name: *vu toro*.

This genus was first reported for the Pacific islands by Reinecke for Samoa *(Sarcocephalus pacifica)* in 1898, and two more species have since been added for that island group. This seems to be the first record of the genus for Fiji.

TIMONIUS Rumph

Timonius affinis A. Gray (fig. 39).

Timonius affinis A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 36, 1860.

"Foliis ovalibus obscure penniveniis, venis subreticulatis, retibus venularum varie hinc inde contrariis;—caeterum praecedentis," that is, "pedunculis fructiferis petiolum aequantibus; pyrenis linearibus, putamine tenui. Feejee Islands."—A. Gray.

Leaves 10-14 cm. long, 3.6-4 cm. broad; petioles 2-3 cm. long; stipules as much as 7 cm. long, often pinkish when young, and soon caducous. Male inflorescences few-flowered; peduncles rather thick, up to 2 cm. long; pedicels somewhat shorter, or none; calyx and corolla as in the female; anthers about 7 mm. long, slender, almost linear, slightly exserted; filaments very short, attached slightly below the middle; rudimentary pistil about 6 mm. long. Female flowers solitary in the uppermost axils; pedicels thick, rigid, 1.5-2 cm. long; calyx about 5 mm. long, truncate, subcylindric or more or less barrel-shaped, in some specimens minutely toothed or notched; corolla faintly fragrant, about 17 mm. long; lobes acute, about 4 mm. long, broadly spreading or reflexed; style about 15 mm. long (including the stigma), the branches 4 to 8, the longest slightly protruding from the corolla tube; anthers present but undeveloped. Fruits subglobose to ovoid, about 13 mm. long, black, shining. In drying, the fleshy part contracts, and the ends of the numerous seeds form small wartlike projections which are arranged in longitudinal rows. Figure 39, *f*, represents a cross section of an immature fruit. The corolla has not yet fallen; corolla and style are thickened and much shorter than those of the unfertilized flower (fig. 39, *d*).

Represented by Parks no. 20891 and Gillespie nos. 2620, 2890, 3106, 3552, 3755.5, 3799, 4292, 4342, 4468, 4512, 4613, and 4817, from the islands of

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Viti Levu, Ovalau, and Taviuni, over an altitudinal range from sea level, at Lami, to the summits of the highest mountains of Tholo North Province.

Timonius affinis grows as high as 8 meters, with a trunk diameter of 10 meters. It is the well known *tiri vanua,* probably so named because its leaves resemble those of the *tiri* (*Rhizophora* sp.). A native of Namosi called it *moka-moka.*

IXORA Linnaeus

Ixora amplexicaulis Gillespie, species nova (fig. 40).

Arbor parva 4 ad 6 m. alta, inflorescentiis exceptis glabra; ramulis gracilibus, teretibus; foliis subsessilibus, 11-15 cm. longis, 4-5.5 cm. latis, oblongis ad oblongo-ellipticis, interdum plus minusve ligulatis, apice acutis ad rotundis, basi cordatis, subamplexicaulibus, nervis primariis utrinque circiter 10, subtus conspicuis; stipulis 5 mm. longis; petiolo 1-2 mm. longo; inflorescentiis plurifloris, valde abbreviatis, confertis, circiter 4 cm. diametro; bracteolis 9 mm. longis, sparse ciliatis; calycibus 8 mm. longis; lobis linearibus, 7 mm. longis, intus et ad marginem leviter ciliatis; corolla glabra, saltem 15 mm. longa; lobis ellipticis, rotundis, 3 mm. longis.

A tree 4-6 meters tall, glabrous throughout except the inflorescences; twigs slender, smooth, terete, or slightly flattened at the extremities. Leaves subsessile, 11-15 cm. long, 4-5.5 cm. broad; blades bright-green and shining above, paler beneath, subcoriaceous, oblong to oblong-elliptic, some more or less strap-shaped, apex acute to rounded, base cordate, subamplexicaul, lateral nerves emerging almost at right angles, about 10 on each side of the midrib, these and the veinlets conspicuous beneath; stipules abruptly acuminate, basal part about 2 mm. long, 3 mm. broad, narrowed part about 3 mm. long; petioles 1-2 mm. long, thick, stout. Inflorescences terminal, many-flowered, greatly abbreviated, crowded, about 4 cm. in diameter. Flowers (Gillespie no. 3753.5) sessile, unexpanded in our specimens; bracteoles about 9 mm. long, linear, sparsely ciliate; calyx about 8 mm. long, lobes linear, about 7 mm. long, 1 mm. broad, lightly ciliate within and at the margins, shortly united at the base; corolla red, glabrous, at least 15 mm. long, lobes elliptic, rounded, about 3 mm. long; stamens about 4 mm. long; filaments slender; stigma-lobes nearly 2 mm. long; style very slender. Fruits glabrous, crimson, subglobose, about 7 mm. in diameter; calyx lobes persistent.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, altitude 1200 meters, July, 1927, H. E. Parks. Type no. 20574. This collection bore fruits only; the immature flowers are described from Gillespie no. 3753.5, collected in the same vicinity. Other collections are: Gillespie nos. 3753 and 3399.9, all from the woods about Nandarivatu. Native names: *lera, sa lera.*

Ixora elegans Gillespie, species nova (fig. 41).

Frutex ad 4 m. altus, inflorescentiis exceptis glaber; ramulis junioribus compressis, vetustioribus teretibus; foliis 12-16 cm. longis, 4-7 cm. latis, chartaceis, nitidis, ellipticis ad oblongo-ellipticis, utrinque obtusis ad acutis; stipulis 4-6 mm. longis, abrupte acuminatis; petiolo ad 2 cm. longo; inflorescentiis usque ad 12 cm. longis, apertis, ramis primariis paucis, patulis, usque ad 10 cm. longis; pedunculis 5 mm. longis; bracteis foliaceis, ovatis ad ellipticis, petiolatis, acutis, 15-23 mm. longis, 5-10 mm. latis; pedicellis circiter 5 mm. longis, tenuibus; bracteolis 1 mm. longis, acuminatis; calycibus 1.5 mm. longis, hispidulis; lobis circiter 0.5 mm. longis, rotundatis, minute ciliatis, quam tubo brevioribus; corolla

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glabra; tubo 6 mm. longo; lobis 4-5 mm. longis, ligulatis, rotundatis; fructibus subglobosis, 9 mm. diametro.

A shrub, about 4 meters tall, glabrous except the inflorescences; twigs slender or stout, flattened when young, later terete. Leaves 12-16 cm. long, 4-7 cm. broad; blades thinly chartaceous, bright-green, shining above and beneath, elliptic to oblong-elliptic, sometimes obovate, obtuse to acute at each end; lateral nerves slightly arched, somewhat ascending, 8 to 12 on each side of the midrib, these and the veinlets rather obscure above, conspicuous beneath; stipules 4-6 mm. long, abruptly acuminate, the narrowed part about 3 mm. long; petioles up to 2 cm. long, stout. Inflorescences terminal, many-flowered, up to 12 cm. long, primary branches spreading, up to 10 cm. long; peduncles about 5 mm. long, stout; bracts foliaceous, ovate to elliptic, petiolate, acute, 15-23 mm. long, 5-10 mm. broad; pedicels about 5 mm. long, slender; bracteoles about 1 mm. long, acuminate, minutely ciliate. Flowers fragrant; calyx about 1.5 mm. long, 1 mm. in diameter, hispidulous, lobes about 0.5 mm. long, rounded, minutely ciliate; corolla crimson, glabrous, tube about 6 mm. long, lobes 4-5 mm. long; 1 mm. broad, elongate, ligulate, rounded, strongly reflexed at maturity; anthers 4-5 mm. long, elongate-acuminate; style filiform, up to 13 mm. long, pilose except the apical part; stigma nearly 3 mm. long, lobes reflexed. Fruits (Gillespie no. 4835) red, hard, subglobose, about 9 mm. in diameter. Seeds flat, about 4 mm. in diameter.

Fiji, Viti Levu, Naitasiri Province, vicinity of Nasinu, about 9 miles from Suva, in open woods, altitude 150 meters, October 24, 1927, John Gillespie. Type no. 3526. Gillespie no. 4835, from which the fruits are described, was collected on the island of Taviuni, on the summit ridge, trail inland from Somo-somo, altitude 1000 meters.

Ixora (§ Phylleilema) nandarivatensis Gillespie, species nova (fig. 42).

Arbor parva, floribus exceptis glabra, ramulis teretibus; foliis 6-9 cm. longis, 1.5-2.5 cm. latis, anguste ellipticis ad oblongo-ellipticis vel lanceolatis, apice acuminatis, basi acutis, rariter rotundatis; nervis obscuris; stipulis aristatis, ad 8 mm. longis; inflorescentiis 3-floris; bracteis 2, foliaceis, late cordatis, sessilibus, subpersistentibus, circiter 17 mm. longis; floribus subsessilibus; calycibus 3 mm. longis, sparse puberulis, lobis brevibus; corollae tubo 2 cm. longo, lobis 6 mm. longis; fructibus late ellipsoideis, 5 mm. longis, calycibus persistentibus coronatis.

A bush or small tree, glabrous except the flowers, with thin, terete twigs. Leaves 6-9 cm. long, 1.5-2.5 cm. broad; blades thinly chartaceous, green above and beneath, somewhat bullate when dry, narrowly elliptic to oblong-elliptic or lanceolate, apex acuminate, mucronate, base narrowed, acute, rarely rounded; primary nerves obscure; stipules aristate, as much as 8 mm. long; petioles about 5 mm. long. Inflorescences 3-flowered, enclosed by two leaf-like, broadly cordate, sessile, subpersistent bracts which are reddish in many specimens, about 17 mm. long. Flowers fragrant, subsessile; calyx about 3 mm. long, sparsely puberulent, lobes short, acute; corolla deep-red to purple; tube narrow, cylindric, about 2 cm. long, lobes contorted in bud, spreading or reflexed, about 6 mm. long, 2 mm. broad, oblong, acute; anthers 3-4 mm. long, exserted on slender filaments; style slender, exserted; stigma thickened, lobes about 1 mm. long. Fruits red, broadly ellipsoid, about 5 mm. long, crowned by the persistent calyx.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, valley of the Singatoka, altitude 900 meters, December 14, 1927, John W. Gillespie. Type no. 4305. Also represented by Parks nos. 20582 and 20585, both from the same area and not found elsewhere. Resembles *Ixora vitiensis* A. Gray, but the leaves are narrower and acute at the base.

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Ixora somosomaensis Gillespie, species nova (fig. 43).

Arbor, partibus junioribus leviter puberulis; foliis 18-25 cm. longis, 9-14 cm. latis, supra glabris, subtus minute puberulis, late ellipticis ad ovatis, apice acutis ad acuminatis, base late acutis ad obtusis; stipulis subulatis, 5-6 mm. longis; inflorescentiis corymbosis breviter pedunculatis; floribus subsessilibus, confertis, pilosis; bracteolis pilosis, linearibus, 5 mm. longis, persistentibus; calycibus pilosis, 5 mm. longis, lobis lineari-lanceolatis, acuminatis, tubo quam longioribus; corolla 15-17 mm. longa, lobis 5 mm. longis; stylis longe exsertis.

A small tree. Twigs stout, rigid, lightly puberulent at the extremities, smooth, terete or slightly flattened. Leaves 18-25 cm. long, 9-14 cm. broad; blades dark-green and glabrous above, paler, minutely and velvety pubescent beneath, moderately thick, broadly elliptic to ovate, apex acute to acuminate, base more or less obtuse and slightly decurrent, lateral nerves tapering, about 9 on each side of the midrib, veinlets more conspicuous beneath than above; petioles stout, 10-15 mm. long; stipules broad at the base, abruptly narrowed, subulate, acuminate, 5-6 mm. long, caducous. Inflorescences many-flowered, axillary or terminal, corymbose, up to 5 cm. in diameter; peduncles about 1 cm. long. Flowers sessile, fascicled, fragrant, the pilose, linear bracteoles about 5 mm. long; calyx grayish pilose within and without, about 5 mm. long, lobes subequal, acuminate, about 3 mm. long; corolla dark-red, glabrous within, pilose without, 15-17 mm. long, tube narrow, cylindric, lobes about 5 mm. long, spreading to strongly reflexed, oblong-ovate; stamens exserted, 4-5 mm. long; anthers oblong-acuminate; filaments about 1 mm. long, attached near the mouth of the tube; pistil up to 2 cm. long; style very slender, long exserted; stigma clavate at first, the lobes later reflexed, up to 2 mm. long. Fruits (Gillespie no. 4828.1) glabrous, red, subglobose, 7 mm. in diameter, the calyx-lobes persistent.

Fiji, Taviuni, slopes of the main range, vicinity of Somo-somo village, altitude 900 meters, March 5, 1928, John W. Gillespie. Type no. 4828, flowering specimen. The fruits are described from another plant, Gillespie no. 4828.1, which grew near by.

Ixora (§ Phylleilema) vitiensis A. Gray (fig. 44).

Ixora (§ *Phylleilema*) *vitiensis* A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 40, 1860.

"Glaberrima; foliis ovato-oblongis acuminatis basi rotundatis, floralibus seu bracteis late cordatis arcte sessilibus capitulum triflorum fulcrantibus; dentibus calycis brevissimis; corolla glabra; stipulus longissime aristatis. Ovolau, Feejee Islands."—A. Gray.

A small tree, glabrous throughout. Leaves 6-9 cm. long, 3-4.5 cm. broad; blades chartaceous, both sides alike, ovate to oblong-elliptic, apex acuminate, often mucronate, base rounded, nerves inconspicuous; stipules aristate, about 6 mm. long; petioles 1-5 mm. long. Inflorescences 3-flowered, enclosed by 2 leaf-like, cordate, sessile bracts about 15 mm. long. Flowers fragrant; calyx about 2 mm. long, lobes short, acute; corolla red, tube very narrow, cylindric, about 14 mm. long, lobes reflexed, about 5 mm. long, oblong; anthers about 3 mm. long, exserted on slender filaments; stigma-lobes about 1 mm. long. Fruits red, obovoid, about 5 mm. long, crowned by the persistent calyx.

Gillespie no. 4009, collected at the type locality on Ovalau, agrees in every essential with the type, of which a photograph is at hand. Gillespie no. 4610, the same species, is from Viti Levu, Rewa Province, limestone hills near the quarry, 4 miles west of Suva along the coast.

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PSYCHOTRIA Linnaeus

Psychotria brackenridgii A. Gray (fig. 45).

Psychotria brackenridgii A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 44, 1860.

"Stipulis caducis; foliis oblongo-lanceolatis utrinque acutis vel acuminatis basi in petiolum longiusculum angustatis fere glabris chartaceis; pedunculis 1-5 terminalibus elongatis cymam trichotomam multifloram gerentibus cum radiis pedicellisque ferrugineo-puberis; fructibus ovalibus 8-costatis truncatis calycis limbo parvo cupuliformi coronatis puberulis; pyrenis tenuiter cartilagineis intus planis dorso convexo carinato-tricostatis. Feejee Islands (in fruit)."—A. Gray.

A shrub or small tree, with rather stout twigs, up to 6 meters tall, generally found in partly shaded situations; young parts puberulent. Leaves 15-25 cm. long, 5-8 cm. broad; blades oblong-elliptic to oblong-obovate, apex generally shortly acuminate but often acute or rounded, base narrowed, acute, lateral nerves about 13 on each side of the midrib, obscure above but very prominent beneath, remarkably uniform in size and almost equidistant; stipules about 1 cm. long, ovate, caducous; petioles 2-5 cm. long. Inflorescences 3-7 (or 10), terminal, many-flowered, trichotomously cymose, 4-10 cm. long; peduncles about equaling the pedicels, both ferruginous-puberulent or sometimes glabrous, the latter branching almost at right angles to the main axis. Flowers inconspicuous; calyx cup-shaped, glabrous or minutely puberulent without, lobes very obtuse, margin ciliate; corolla funnel-shaped, about 11 mm. long, lightly pilose without, especially towards the base, with whitish hairs, densely pilose on the inside below the middle, lobes about 2 mm. long, oblong, rounded, strongly reflexed; anthers about 1.5 mm. long, exserted; filaments about 3.5 mm. long; style slender, about 4 mm. long; stigma-lobes about 1 mm. long. Fruits greenish or (at maturity) red, smooth or puberulent, soft, fleshy, about 13 mm. long, 9 mm. broad, ellipsoid, apex crowned by the cupuliform calyx-limb; seeds thin, plane within, dorsally convex, 3-ribbed, the middle one stronger than the others, erose. When dry the fruits appear truncate at the apex, and 8-ribbed.

Common in the forests of the southeastern provinces of Viti Levu, in Naitasiri, Rewa, Namosi, and Serua; one specimen from Tholo North Province, slopes of Loma Langa Mountain, altitude 1000 meters. The forms most similar to a photograph of the type are from Rewa Province, slopes of Korombamba Mountain, represented by Parks no. 20111, and Gillespie nos. 2140 and 2249 (the subject of figure 45). Detailed parts were drawn from material preserved in alcohol.

Psychotria filipes A. Gray (fig. 46).

Psychotria filipes A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 46, 1860.

"Glabra; stipulis caducis; foliis lanceolato seu obovato-oblongis acuminatis basi paullo angustata saepius subcordatis longe petiolatis; pedunculis terminalibus 2-5 filiformibus folia subaequantibus cyman effusam plurifloram gerentibus, radiis 3-4 pedicellisque gracilibus; calycis limbo crateriformi 4-dentato ovario breviore; corolla brevi 4-fida fauce fere nuda, fructu immaturo ovato. Feejee Islands."—A. Gray.

A glabrous shrub, young twigs 2-sided, at length terete. Leaves 10-15 cm. long, 4.5-7 cm. broad; blades chartaceous, ovate-oblong to oblanceolate, apex acuminate, base

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narrowed, rounded to shortly cordate or truncate, lateral nerves 11-13 on each side of the midrib, ascending, obscure above, prominent beneath, with indistinct veins; petioles 2-4 cm. long, rather stout. Inflorescences terminal, ascending, many-flowered, as much as 10 cm. long; peduncles 2-6, often branching near the base, very slender, almost filiform; pedicels 4-12 mm. long. Flowers red, many 4-merous, glabrous; calyx about 2 mm. long, limb scarcely as long as the ovary, lightly lineate when dry, lobes obtuse, abruptly acuminate; corolla funnel-shaped, about 4 mm. long, lobes about 2 mm. long, ovate, rounded; anthers about 1 mm. long, thick, exserted on rather stout filaments.

This species is represented by Gillespie nos. 2861 and 2876, from Viti Levu, Namosi Province, on wooded ridges near the village of Namosi. These specimens have been compared with a photograph of the type, and they agree in essentials. Gillespie no. 2861 is the subject of figure 46. Native name: *kau thok i ni vole.*

Psychotria pickeringii A. Gray (fig. 47).

Psychotria pickeringii A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 47, 1860.

"Glabra; stipulus caducis; foliis oblongo-lanceolatis seu obovate-oblongis promisse acuminatis base angustata subacutis obtusisve; capitulo arcte sessile plurifloro bracteis squamaceis caducis involucrate; calycis limbo brevissimo truncato; corolla tubulosa 4-6-mera; fructibus obovatis obtusis basi quadrangulatis, pyrenis dorso et inferne marginibus cristatis. Feejee Islands."—A. Gray.

A shrub, glabrous except the flowers. Leaves very variable in size, even on the same twig, generally 7-11 cm. long, 2.5-4 cm. broad; blades chartaceous, green above, paler beneath, obovate to oblong-elliptic, apex acuminate to caudate, base narrow, subacute to obtuse, lateral nerves 8-11 on each side of the midrib, obscure above, rather prominent beneath; stipules caducous; petioles 8-18 mm. long. Inflorescences terminal, many-flowered, capitate, at first enclosed in red, squamaceous, caducous bracts, which are enlarged at the base and as much as 12 mm. long before splitting irregularly. Flowers sessile, faintly fragrant, variable in character; calyx truncate, cup-shaped, about 2.5 mm. long, some glabrous, some reddish pubescent without. Corollas in some plants glabrous, about 10 mm. long, tube cylindric, lobes about 2 mm. long, acute; anthers about 1.2 mm. long, exserted; filaments very short; other flowers with corollas hairy in the throat, about 6 mm. long, the tube thicker and lobes about 3 mm. long. Fruits obovate, obtuse, 4-angled when dry.

Represented by Parks nos. 20006, 20117, and 20866; Gillespie nos. 2137, 2192, 2278, 2318, 2345, 2984, 3046, 3117, 3250, and 3595. A very common species in the southeastern province of Viti Levu, but extending as far as Naitarandamu Mountain in Namosi Province. Figure 47 was drawn from Gillespie no. 3046.

Psychotria taviunensis Gillespie, species nova (fig. 48).

Arbor parva, partibus junioribus puberulis; foliis tenuiter chartaceis, supra glabris, 16-23 cm. longis, 8-11 cm. latis, ellipticis ad obovatis, apice acuminatis, basi angustatis et truncatis vel breviter cordatis, nervis primariis subtus perspicuis, pubescentibus; petiolis 2-4 cm. longis; inflorescentiis laxis, multifloris, 2.5-6 cm. longis; pedunculis 4-7, griseo-pubescentibus; floribus inconspicuis, vix 5 mm. longis; corollae lobis patulis.

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A small tree, with young parts minutely puberulent. Leaves 16-23 cm. long, 8-11 cm. broad, clustered at the extremities of the twigs; blades thinly chartaceous, elliptic to obovate, apex acuminate, base narrowed, truncate or slightly cordate, lateral nerves numerous, obscure above, prominent and brownish pubescent beneath; petioles 2-4 cm. long, rather stout, puberulent. Inflorescences terminal, somewhat lax, many-flowered, 2.5-6 cm. long; peduncles 4-7, brownish or grayish pubescent; pedicels about 3 mm. long. Flowers inconspicuous; calyx cupulate, obscurely lobed, glabrous, about 1.5 mm. long and broad; corolla white, campanulate, glabrous, tube scarcely 1 mm. long; lobes spreading, about 4 mm. across, acute; anthers about 1 mm. long, strongly exserted on slender filaments. Fruits (immature) greenish, ovoid, as much as 7 mm. long.

Fiji, Taviuni, vicinity of Waiyevo (northwest coast), in dense woods above the coconut plantations, altitude 450 meters, February 27, 1928, John W. Gillespie. Type no. 4722.

READEA Gillespie, genus novum

Calycis tubus obconicus; limbus brevis, lobis 4, patentibus, reflexis, elongatis, ceraceis, corollae similimis, deciduis. Corollae tubo anguste cylindraceo, fauce infundibuliformi nuda; lobis 4, elongatis, reflexis, quam calycis segmentis minoribus et cum iliis alternantibus, valvatis. Stamina 4, tubo corollae inserta; filamentis brevibus; antherae, elongato-oblongae, subinclusae, dorse affixae. Discus carnosus, elevatus. Ovarium 2-loculare; stylus brevis; filiformis, glaber, ramis 2 filiformibus; ovula in loculis solitaria e basi erecta cuneata, apice truncata, leviter bilobata, dorso canaliculata. Fructus carnosus, obovoideus ad ellipsoideo-cylindraceus, rotundato-truncatus, ad apicem plus-minusve sulcatus. Semina 2, plano-convexa; extus leviter 3-carinata, albumine aequabili, corneo; embryo parvus, rectus, oblongus, in basi albuminis, cotyledonibus ovatis radicula brevioribus. Arbor vel frutex, glabra. Folia opposita, petiolata. Stipulae intrapetiolares, in vaginam connatae, caducae. Flores in cymas terminales.

This proposed new genus belongs in the tribe Psychotrieae as defined by Bentham and Hooker f.; it is related to *Psychotria* Linnaeus and *Calycosia* A. Gray, but differs from both in the extraordinary development of the calyx, which is waxy when fresh and similar to the corolla in size, texture, and appearance. The calyx-lobes are of equal size, and are strictly alternate with those of the corolla.

The generic name is in honor of John Moore Reade, Ph. D., Professor of Botany in the University of Georgia, my friend and former teacher.

Readea membranacea Gillespie, species nova (fig. 49).

Arbor parva glabra, ramis tenuibus; follis 11-20 cm. longis, 3-8 cm. latis, membranaceis, oblongis ad oblongo vel obovato-ellipticis, apice angustatis, longe acuminatis ad caudatis; stipulis caducis, 2.5 mm. longis; petiolo 2-4 cm. longo; inflorescentiis terminalibus, laxis, 5- ad 9-floris, usque 10 cm. longis latisque; pedunculo 4 cm. longo; floribus 2 cm. longis, calyce infundibuliformi, tubo 6-8 mm. longo, lobis 9 mm. longis, 5 mm. latis; corolla infundibuliformi, tubo 2-4 mm. longo, lobis 7 mm. longis, patulis, reflexis; antheris 3.6 mm. longis; fructibus 2.5 cm. longis, subcylindraceis, apice truncatis, ad apicem leviter 8-sulcatis.

A small, glabrous tree, with thin, dark-brown branches. Leaves few, clustered at the extremities of the twigs, 11-20 cm. long, 3-8 cm. broad; blades membranaceous,

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flexible in life, bright-green above and beneath, oblong to oblong- or obovate-elliptic, apex narrowed, obtusely to long-acuminate or even caudate, base acute; lateral nerves 9 to 12 on each side of the midrib, moderately conspicuous above and beneath, veinlets indistinct; stipules caducous, oblong-lanceolate to ovate-lanceolate, acuminate, about 2.5 mm. long, the stipule sheath truncate, about 1 mm. long; petioles 2-4 cm. long. Inflorescences lax, terminal, 5-9-flowered, as much as 10 cm. long and wide; peduncles moderately stout, often 4 cm. long, branches generally 1 or 2 pairs, at right angles to the main axis; pedicels about 1 cm. long; bracts 1 to 2 mm. long, acute. Flowers pale-green, waxy when fresh, about 2 cm. long, with a faint odor of peppermint; calyx funnel shaped; ovary about 5 mm. long, cylindric or slightly conic, about 2 mm. thick; calyx-tube 6-8 mm. long, lobes about 9 mm. long, 5 mm. broad, apex acute to rounded; corolla funnel-shaped, glabrous within, tube 2-4 mm. long, 2.5 mm. thick, lobes about 7 mm. long, spreading, reflexed, about 2 mm. broad, oblong, apex acute; anthers slightly exserted, about 3.6 mm. long, elongate; filaments very short; disc elevated, obconic, about 1.5 mm. high; style filiform; stigma lobes 1 mm. long. Fruits dark-red, about 2.5 cm. long, 1.6 cm. thick, subcylindric, apex truncate, lightly 8-sulcate towards the apex which has a shallow, annular depression about 9 mm. in diameter, base narrowed; seeds hard, about 10 mm. long, 5 mm. broad, 1.5 mm. thick, oblong, narrowed at the base, with 3 dorsal, subprominent ridges; endosperm uniform, horny, oily.

Fiji, Taviuni, vicinity of Waiyevo (northwest coast), banks of streams in the coconut plantations, altitude 200 meters, February 22, 1928, John W. Gillespie. Type no. 4622. Other collections representing this species are: Gillespie nos. 3431, 4056, 4647, 4654, 4711.5, and 4810.5, giving an additional range in Viti Levu (Naitasiri and Tholo North provinces). The Naitasiri plant has much broader leaves than the other specimens.

URAGOGA Linnaeus

Uragoga lageniformis Gillespie, species nova (fig. 50).

Frutex erectus, subglaber ramulis junioribus compressis, demum teretibus; foliis 15-25 cm. longis, 3.5-6 cm. latis, glabris, paullulo bullatis, oblongis ad oblongo-lanceolatis vel ellipticis vel obovatis, apice subacuminatis, basi decurrentibus; petiolo crasso, 1-3 cm. longo; inflorescentiis solitariis, terminalibus, lageniformibus; pedunculo crassissimo, 1.5-4 cm. longo; involucri bracteae chartaceae, demum ab apice discissae, 2.5 cm. longa; floribus glabris, in capitulo 5 ad 8, confertis, sessilibus, sub anthesin singuli exsertis, calyce 18 mm. longo, membranaceo, lobis 3 mm. longis, acutis; corolla 3.5 cm. longa, angusta, cylindrica, membranacea, lobis 4 mm. longis, reflexis; antheris inclusis.

A subglabrous shrub; twigs at first flattened, finally terete. Leaves 15-25 cm. long, 3.5-6 cm. broad; blades glabrous, chartaceous, often slightly bullate, dark-green above, paler beneath, blackening when dried, oblong to oblong-lanceolate to elliptic or obovate, apex subacuminate, base somewhat decurrent, lateral nerves arcuate, about 12 on each side of the midrib, moderately conspicuous, veinlets few, obscure; stipules acute, about 4 mm. long, fimbriate, caducous, the scar ciliate with brown hairs; petioles stout, 1-3 cm. long. Inflorescences solitary, terminal; peduncles very stout, 1.5-4 cm. long; involucral bract chartaceous, flask-shaped, finally splitting from the summit, about 2.5 cm. long, 1.6 cm. thick. Flowers glabrous, 5 to 8 in a head, crowded, sessile, exserted singly at anthesis; bracteoles about 2 cm. long, 5 mm. broad, chartaceous, broadly acute, margins thin and some ragged; calyx about 18 mm. long, tubular, somewhat saccate, membranaceous, lobes about 3 mm. long, acute to acuminate; corolla about 3.5 cm. long, narrow, tubular, membranaceous, lobes about 4 mm. long, oblong, rounded, reflexed; anthers about 2.5 mm. long, included; filaments very short, inserted near the summit of the tube; style very slender, slightly exserted; ovary about 3 mm. long, cylindric. Fruits unknown.

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Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, upper slopes of Loma Langa Mountain, altitude 1100 meters, November 14, 1927, John W. Gillespie. Type no. 3688. Also represented by Gillespie no. 4286, from the same locality. Native name: *kau alewa,* meaning "the woman's tree." The same name is given to certain species of *Cyrtandra,* and to *Saurauia rubicunda*; its significance I do not know.

Uragoga petiolata (A. Gray) Gillespie, combinatio nova (fig. 51).

Calycosia petiolata A. Gray, Amer. Acad. Arts and Sci., Proc., vol. 4, p. 48. 1860.

"Foliis obovatis seu obovato-lanceolatis in petiolum attenuatis; calyce breviter 5-lobo, lobis oblongis; pyrenis dorso haud costatis. Feejee Islands."—A. Gray.

A small tree, young parts and flowers hirsute with brownish hairs; twigs at first flattened, finally glabrous, terete, and often very thick. Leaves as much as 40 cm. long and 13 cm. broad; blades glabrous, chartaceous to subcoriaceous, slightly bullate, oblong-elliptic to obovate, apex acute to obtusely acuminate, the tip often rounded, base narrowed, acuminate, lateral nerves arcuate, ascending, about 15 on each side of the midrib, veinlets few, obscure; stipules as much as 4 cm. long, 1.5 cm. broad, very hairy at the base, caducous; petioles stout, as much as 8 cm. long. Inflorescences solitary, lateral and terminal; heads subglobose, 7-12-flowered, about 2.5 cm. long and thick; peduncles fleshy, about 1.5 cm. long, irregularly branched; involucral-bract chartaceous, lineate, hirsute with brownish hairs, especially near the summit, sparsely papillate-bristly within at the base, and splitting irregularly, leaving a jagged, fimbriate margin; bracteoles about 2 cm. long, as much as 12 mm. broad, chartaceous, dorsally hirsute, especially near the summit, margin ragged. Flowers subsessile; calyx about 14 mm. long, tubular, chartaceous, finely sculptured, outside sparsely pilose with whitish hairs, glabrous within, lobes about 4 mm. long, oblong, apex rounded, margin very pilose; corolla white, about 17 mm. long, tubular, chartaceous, tube nearly glabrous without, pilose within, lobes about 3 mm. long, rounded, the tips thickened, margin pilose; stamens about 4 mm. long; anthers oblong, slightly exserted, longer than the slender filaments; ovary about 4 mm. long, cylindric; style about 12 mm. long, slender; stigma lobes short. Fruits reddish, glabrous, oblong, obscurely angulate by compression, apex truncate, base narrowed, obtuse to acute or subtruncate, about 10 mm. long, 7 mm. thick, calyx long persistent, deciduous, leaving a shallow annual depression at the summit of the fruit; seeds subcordate, about 6 mm. long, 2.5 mm. broad, 1 mm. thick, plane within, concave without, not at all or very slightly ridged.

A photograph of the type of *Calycosia petiolata* A. Gray (in the Gray Herbarium) reveals the fact that it consists of a twig about 1 cm. long bearing two leaves and about two fruits. This accounts for the inadequacy of the original description. From the description and photograph I confidently identify with this species Parks no. 20432 from Viti Levu, Naitasiri Province, at Viria, and Gillespie nos. 4507 and 4455, from Ovalau, mountains west of Levuka, altitude 400 meters. The botanists of the Wilkes Exploring Expedition ascended these mountains, and this is probably the type locality for the species. Flowers and fruits of Gillespie no. 4507 were preserved in alcohol, from them and the dried material figure 51 was drawn.

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CALYCOSIA A. Gray

Calycosia fragrans Gillespie, species nova (fig. 52).

Arbor parva, floribus exceptis glabra, ramis vetustioribus teretibus; foliis 7.5-10 cm. longis, 2-3 cm. latis, chartaceis, oblongo-ellipticis ad obovatis, apice subacuminatis, basi obtusis, petiolo circiter 1 cm. longo; inflorescentiis solitariis, terminalibus, foliis subaequantibus, multifloris; pedunculo 2 cm. longo; calycis tubo campanulato, 8 mm. diametro, perspicue lineato, lobis obtusissimis, ad marginem ciliolatis; corolla 18-25 mm. longa, tubo angustissime cylindrico-infundibuliformi, extus hispidulosa, lobis 3 mm. longis; antheris 3 mm. longis, basi profunde furcatis.

A small tree, glabrous except the flowers; twigs slender, flattened and 2-angled when young, later terete. Leaves 7.5-10 cm. long, 2-3 cm. broad; blades chartaceous, oblong-elliptic to obovate, apex subacuminate, the tip rounded, base generally obtuse, very slightly decurrent, lateral nerves ascending, about 9 on each side of the midrib, obscure above, rather prominent beneath, veinlets indistinct; stipules caducous, the scars ciliate with brown hairs; petioles about 1 cm. long. Inflorescences solitary, terminal, subequaling the leaves, many-flowered; bracts 2, leaf-like, about 15 mm. long, the blade oblong-elliptic; peduncles stout, about 2 cm. long; pedicels rather slender, often 8 mm. long. Flowers conspicuous; calyx pinkish, campanulate, about 8 mm. in diameter, the limb and lobes conspicuously lineate, the latter very obtuse, ciliolate at the margins; corolla white, 18-25 mm. long, tube very narrowly cylindric-infundibuliform, often curved, hispidulous without, woolly hirsute within, especially at the middle, lobes oblong, acute, about 3 mm. long, spreading or reflexed, the margins hispid; ovary glabrous, more or less cylindric, about 2 mm. long, disc hemispheric, 1 mm. long; style filiform, about 16 mm. long; stigma-lobes often 1.5 mm. long; anthers versatile, narrowly oblong, about 3 mm. long, deeply forked at the base. Fruits (immature) obovoid, as much as 5 mm. long, calyx limb decurrent.

Fiji, Viti Levu, Namosi Province, slopes of Naitarandamu Mountain, 1000 meters altitude, September 27, 1927, John W. Gillespie. Type no. 3085.

Calycosia laxiflora Gillespie, species nova (fig. 53).

Arbor parva glabra, nodis ramulorum incrassatis; foliis 8-11 cm. longis, 2-3.5 cm. latis, submembranaceis, obovatis ad oblongo-ellipticis, apice acuminatis, interdum subcaudatis, basi acutis ad obtusis; petiolo 1-2 cm. longo; inflorescentiis terminalibus, circiter 9 cm. longis; pedunculis 3-7, filiformibus, laxis, 3- ad 5-floris, pedicellis 12 mm. longis; calyce subcampanulato, 6 mm. longo; corolla ceracea, infundibularis, 2 cm. longa, intus leviter pruinosa, lobis 3 mm. longis, triangularis; fructibus obovoideis, in siccatate valde 6-costatis, 1 cm. longis, limbo calycis persistenti.

A small, glabrous tree, with brown, terete twigs which are somewhat thickened at the nodes. Leaves 8-11 cm. long, 2-3.5 cm. broad; blades pale-green, submembranaceous, clustered at the extremities of the twigs, obovate to oblong-elliptic, apex acuminate, sometimes subcaudate, base acute to obtuse, slightly decurrent, lateral nerves about 8 on each side of the midrib, ascending, moderately prominent on both sides, veinlets very indistinct; stipules caducous; petioles slender, 1-2 cm. long. Inflorescences terminal, about half as long as the leaves; peduncles 3 to 7, filiform, lax, about 3 cm. long, 3- to 5-flowered; pedicels about 12 mm. long, filiform; bracts minute. Flowers conspicuous; calyx membranaceous, broadly obconic to campanulate, about 6 mm. long, the lobes 1.5-2.5 mm. long, rounded; corolla white, waxy, funnel-shaped, lightly pruinose within, about 2 cm. long, 5 mm. thick at the throat, lobes often 3 mm. long, broadly triangular, apex rounded; disc hemispheric, often 2 mm. high; style filiform, about 10 mm. long; stigma-lobes broad, about 1 mm. long; anthers oblong, 1 mm. long, equaling the filaments. Fruits obovoid, strongly 6-ribbed when dry, about 1 cm. long, crowned by the persistent calyx-limb; seeds 5 mm. long and broad, 3-ribbed toward the apex.

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Fiji, Viti Levu, Tholo North Province, slopes of Mount Victoria (Tamani Ivi), altitude 1100 meters, November 29, 1927, John W. Gillespie. Type no. 4116. Also represented by Parks nos. 20809, 20824, and 20836, all from the slopes and summit of Mount Victoria, where it is common among the small trees and shrubbery.

This species resembles *Calycosia glabra* Turrill, but differs in having smaller, acuminate leaves and smaller flowers.

Calycosia magnifica Gillespie, species nova (fig. 54).

Arbor parva, floribus exceptis glabris; foliis chartaceis, 14-19 cm. longis, 3.5-5.5 cm. latis, oblongo- ad obovato-ellipticis, apice acutis, basi acutis interdum decurrentibus; inflorescentiis terminalibus, diffusis, multifloris, foliis subaequantibus; floribus conspicuis; calycibus albis, campanulatis; ovario 3 mm. longo, pubescenti; limbo maxime expanso, 12 mm. diametro; corolla usque ad 2.5 cm. longa, extus pubescente.

A small tree, glabrous except the flowers. Leaves 14-19 cm. long; 3.5-5.5 cm. broad; blades chartaceous, rather dark green above and beneath, oblong- to obovate-elliptic, apex acute to subacuminate, base acute or decurrent; lateral nerves 8-12 on each side of the midrib, inconspicuous above, subprominent beneath; veins obscure. Inflorescences terminal, many-flowered, diffuse, about equaling the leaves in length; peduncles stout, about 3 cm. long to the first branches which are 3 to 7 in number; pedicels slender, about 1 cm. long. Flowers odorless, conspicuous; calyx campanulate, white, ovary about 3 mm. long, cylindric, pubescent, limb greatly expanded, about 12 mm. across, lobes about 3 mm. long, reflexed, pubescent within; anthers about 4 mm. long, slightly exserted; filaments slender, attached near the throat. Fruits unknown.

Fiji, Viti Levu, Namosi Province, ridges of Naitarandamu Mountain, altitude 1000 meters, September 28, 1927, John W. Gillespie. Type no. 3307.1.

An attractive tree; the white calyces are most showy, as seen against dark foliage in the gloom of the cloud-topped mountain.

Calycosia monticola Gillespie, species nova (fig. 55).

Arbor parva glabra; foliis in siccate flavido-viridibus, ascendentibus, circiter 7 cm. longis, 19 mm. latis, oblongo-obovatis ad ellipticis, utrinque acutis; petiolo 1 cm. longo; inflorescentiis terminalibus foliis subaequantibus, pedunculo 2.5 cm. longo; calyce 6 mm. longo, corolla anguste infundibularis, extus glabra, lobis patulis vel reflexis, 3 mm. longis; stylo tenui, 11 mm. longo, lobis 4 mm. longis; fructibus obovoideis, 7 mm. longis.

A small tree, glabrous throughout, with rather slender, terete or striate, ascending twigs. Leaves yellowish-green when dry, ascending, thickly clustered at the extremities of the twigs, rather uniform in size, about 7 cm. long, 19 mm. broad; blades oblong to oblong-obovate or elliptic, apex obtuse to acute or slightly acuminate, base acute, lateral nerves obscure above, subprominent beneath, about 8 on each side of the very conspicuous midrib; stipules connate; petioles 1 cm. long or less. Inflorescences terminal, partly concealed by the leaves, or, at most, only the flowers surpassing them; peduncles solitary, moderately stout, about 2.5 cm. long, once or several times branched; pedicels often 3 mm. long, calyx about 6 mm. long, ovary conic, about 1.5 mm. long, limb green, chartaceous, subcylindric, about 2 mm. thick, lobes obtuse to acute, scarcely 1 mm. long; corolla white, narrowly infundibuliform, glabrous without, farinose to more or less arachnoid within, as much as 2.5 cm. long, lobes triangular, broadly spreading or reflexed, about 1 cm. across; disc erect, about 2 mm. high and thick; style slender, about 11 mm. long; stigma

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branches flattened, about 4 mm. long; anthers elongate, often 3 mm. long; filaments about 2 mm. long. Fruits green, obovoid, about 7 mm. long, 6-ribbed when dry.

Fiji, Viti Levu, Namosi Province, trail up Voma Mountain from Namosi village, altitude 600 meters, September 11, 1927, John W. Gillespie. Type no. 2896. Also represented by Gillespie nos. 2677, 2722, 2784, and 2795.

This species is fairly common on Voma Mountain from middle elevations to the summit, but not as yet found elsewhere.

MORINDA Linnaeus

Morinda bucidifolia A. Gray (fig. 56).

Morinda bucidaefolia A. Gray: Am. Acad. Arts and Sci., Proc., vol. 4, p. 41, 1860.

"Glabra, scandens; stipulis subdistinctis; foliis obovato-cuneatis obtusis vel retusis coriaceis supra nitidulis subtus venulis inter costas rectas prominulas crebre reticulatis; pedunculis plurimis terminalibus; capitulo globoso 7-10-floro. Feejee Islands."—A. Gray.

A subglabrous vine, with twining, shallowly caniculate stems as much as 8 mm. thick. Leaves 6-10 cm. long, 3.5-5 cm. broad; blades coriaceous, yellowish when dry, characteristically obovate, but variable, sometimes elliptic, oblanceolate, or cuneate, apex obtuse, rounded or retuse, sometimes obtusely cuspidate, lateral nerves about 5 on each side of the midrib, axils nude, veins beneath numerous, prominent, reticulate; stipules membranaceous, indistinct, as much as 4 mm. long; petioles about 1.5 cm. long. Inflorescences terminal; peduncles about 8, 1-2 cm. long, rather slender, sparsely hispidulous; flowering heads globose, often 4 mm. in diameter (not including the corollas); calyx glabrous, about 1.5 mm. in diameter, cupulate, truncate, or obscurely toothed; corolla sparsely pilose without, often 2.5 mm. long, funnel-shaped, lobes ovate, rounded, about 1 mm. long, spreading and often reflexed, villous-barbate within with whitish hairs; anthers about 1.5 mm. long, slightly exserted; syncarpia globose, about 8 mm. in diameter.

Represented by Parks nos. 20311, 20637, and 20899; Gillespie nos. 2194, 2493, 2741, 2743, 2826, 3100.5, 3191, 3370, and 3673. Common in the eastern provinces of Viti Levu. Specimens from the vicinity of Suva agree most closely with a photograph of the type, the leaves of which are about 7 cm. long. The Tholo North Province plants generally have smaller leaves, in one form (Gillespie no. 3191) less than 4 cm. long, in shape, spathulate. Native name: *wa vani* or *wa pani*.

Morinda nandarivatensis Gillespie, species nova (fig. 57).

Frutex scandens, floribus exceptis glaber; ramulis obscure 4-angulatis, cortice chartaceo; foliis 5-8 cm. longis, 1.8-2 cm. latis, ellipticis, utrinque acutis, base paullo decurrentibus; nervis primariis utrinque 5-7, subprominentibus, axillis glandulosis, haud barbellatis; inflorescentiis terminalibus; pedunculis 4-7, gracilibus, 2-3 cm. longis; floribus circiter 4 mm. longis, extus glabris, intus hirsutis; syncarpio globoso, 1 cm. diametro.

A vine, glabrous except the flowers. Twigs slender, obscurely 4-angled, with papery bark. Leaves 5-8 cm. long, 1.8-2.5 cm. broad, somewhat erect; blades chartaceous, paler

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beneath than above, elliptic, both ends acute, base slightly decurrent; lateral nerves 5 to 7 on each side of the midrib, moderately conspicuous above and beneath, axils glandular but not barbellate, veins reticulate, inconspicuous; petioles about 1.5 cm. long, slender; stipules pale-brown, papery, erose, often 2 or even 3 mm. long, conspicuous, especially on young twigs. Inflorescences terminal; peduncles 4-7, slender, erect, 2-3 cm. long; capitula 9- to 12-flowered, subglobose, about 4 mm. in diameter (not including the corollas). Flowers about 4 mm. long, yellow; corolla-tube glabrous without, hirsute within with whitish matted hairs, lobes about two-thirds united, acute, strongly reflexed; anthers 0.7 mm. long, oblong-sagittate, longer than the filaments, slightly exserted; style about 2 mm. long, exserted; stigma-lobes about 1 mm. long, broad, flattened. Syncarps subglobose, about 1 cm. in diameter.

Fiji, Viti Levu, Tholo North Province, vicinity of Nandarivatu, slopes of Loma Langa Mountain, altitude 1200 meters, November 16, 1927, John W. Gillespie. Type no. 3786. Gillespie no. 4123 is another specimen from the same locality.

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FIGURE 1.—*Maesa densiflora* Gillespie: *a*, portion of corolla; *b*, prophyllum; *c*, pistil and calyx with corolla removed.

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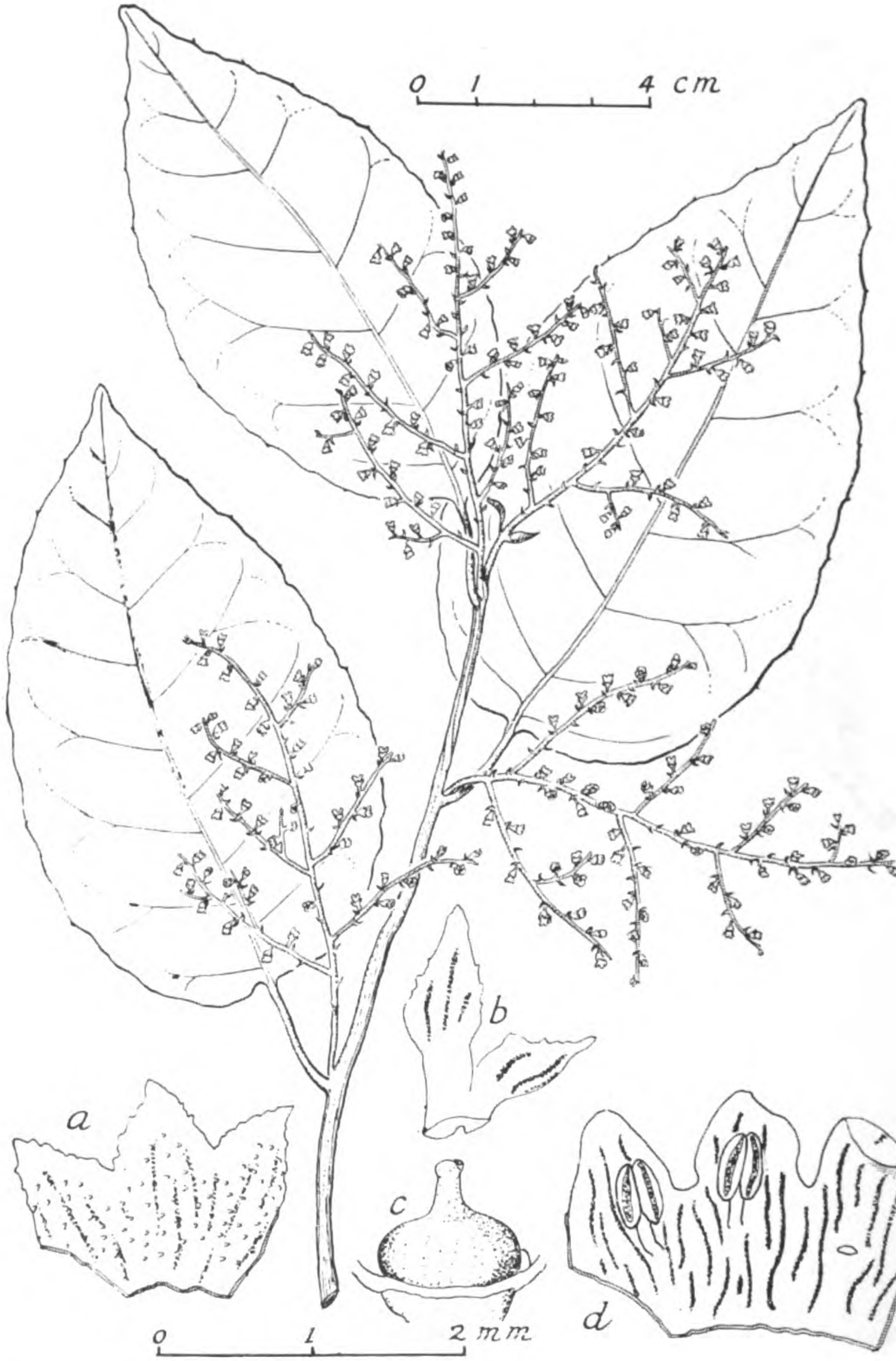

FIGURE 2.—*Maesa grandis* Gillespie: *a*, portion of calyx; *b*, prophyllum; *c*, pistil; *d*, portion of corolla.

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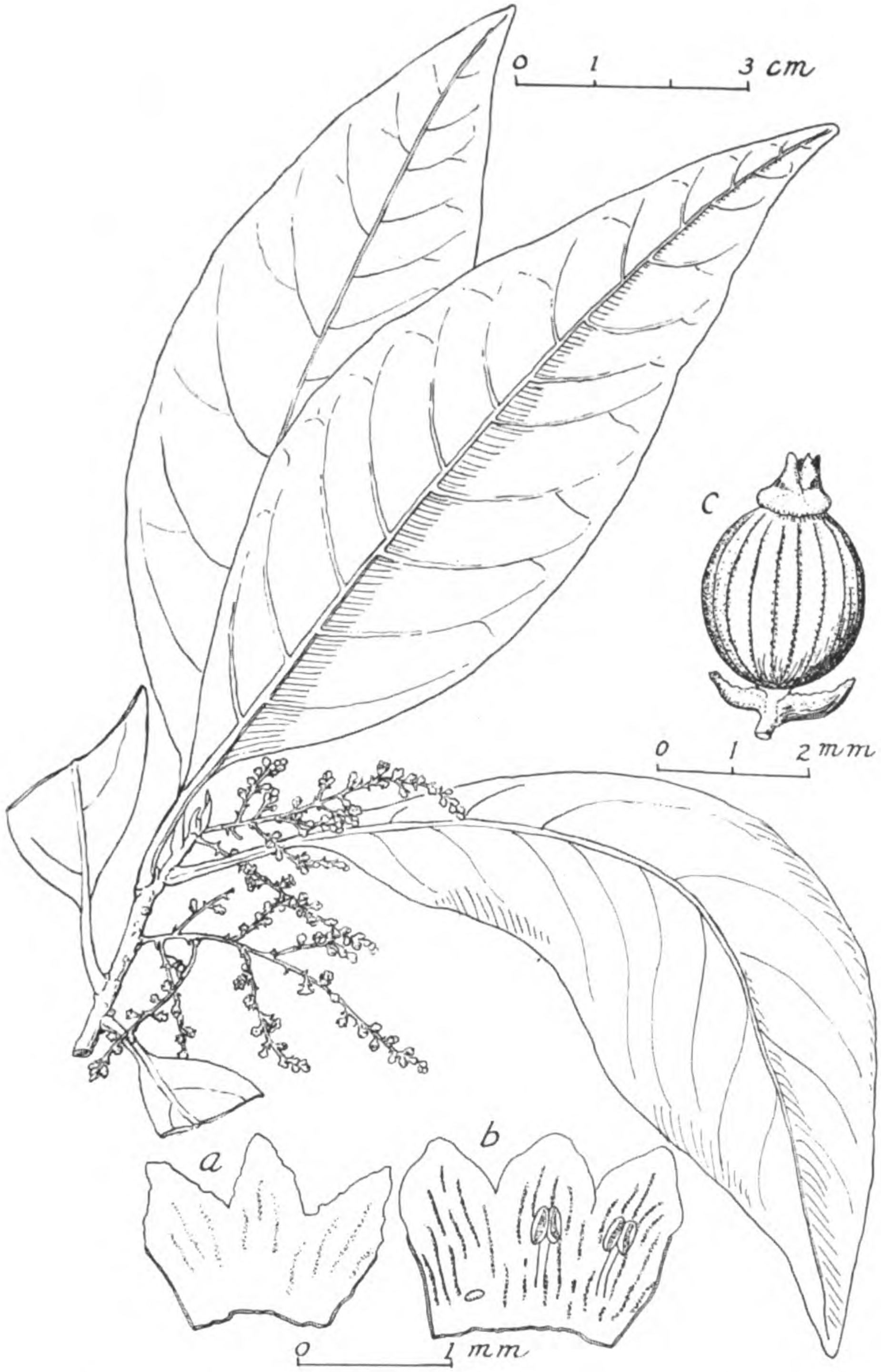

FIGURE 3.—*Maesa insularis* Gillespie: *a*, portion of calyx; *b*, portion of corolla; *c*, fruit.

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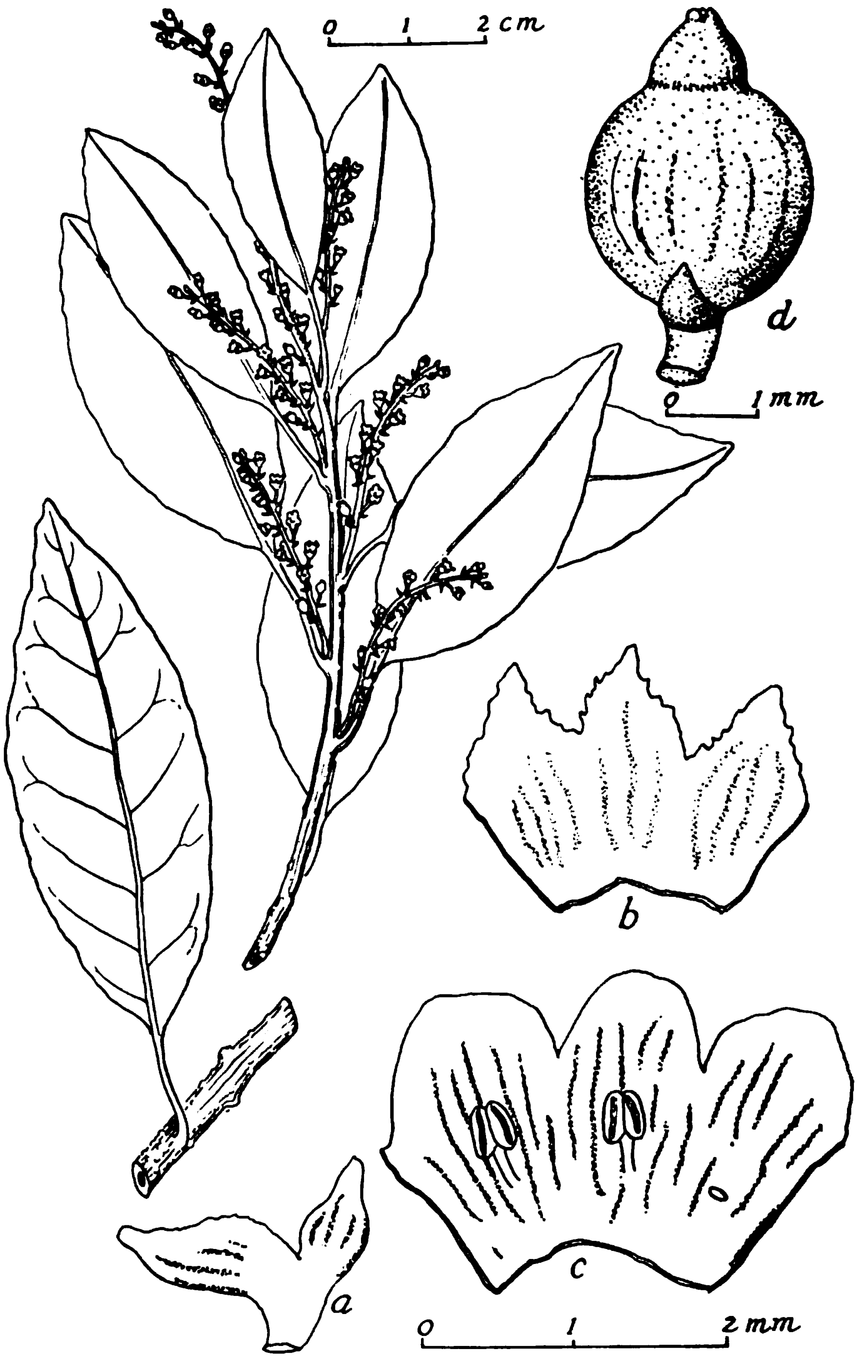

FIGURE 4.—*Maesa lenticellata* Gillespie: *a*, prophyllum; *b*, portion of calyx; *c*, portion of corolla; *d*, fruit.

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FIGURE 5.—*Maesa neriifolia* Gillespie: *a*, prophyllum; *b*, portion of calyx; *c*, pistil; *d*, portion of corolla.

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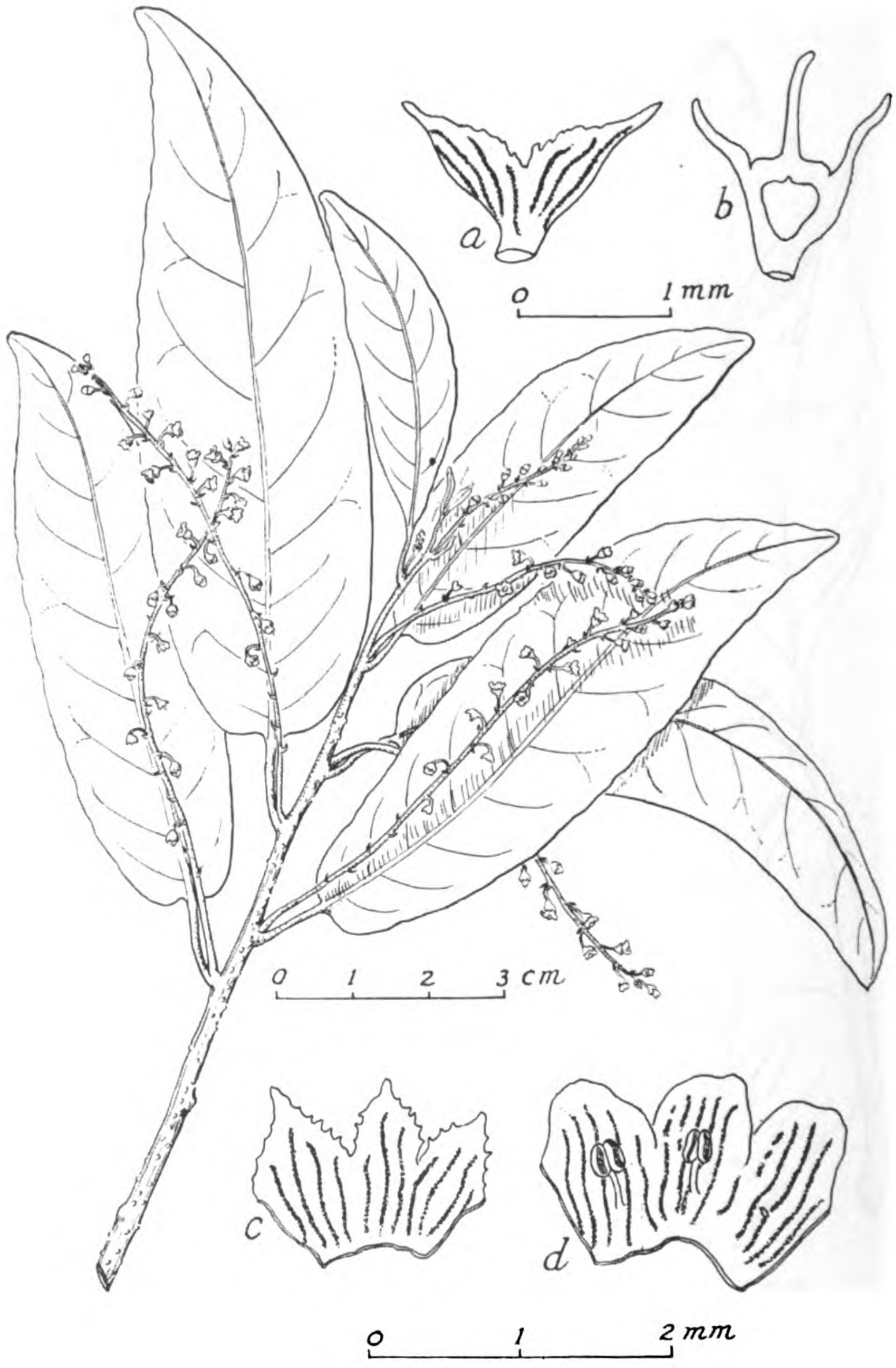

FIGURE 6.—*Maesa parksii* Gillespie: *a*, prophyllum; *b*, section through pistil; *c*, portion of calyx; *d*, portion of corolla.

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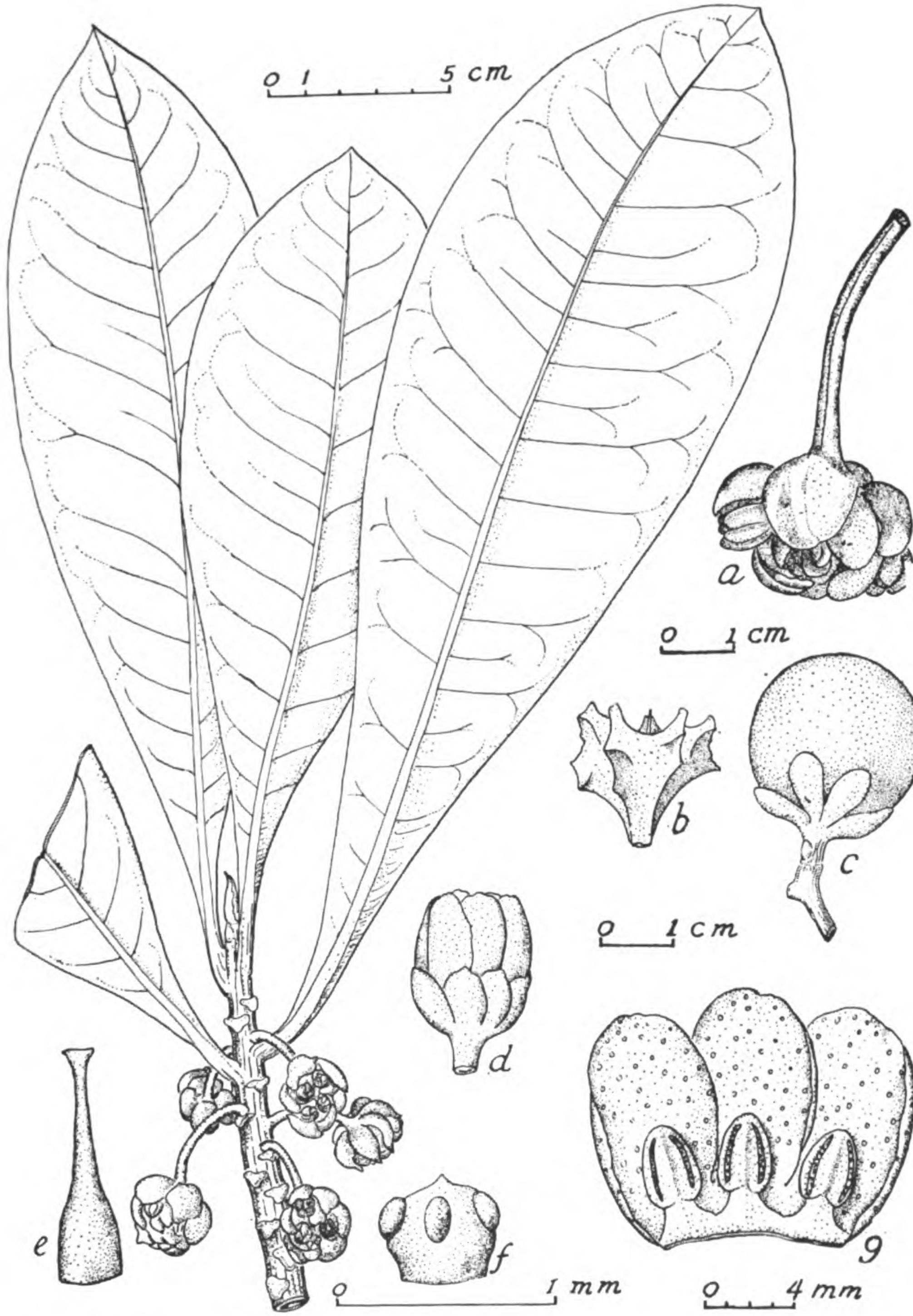

FIGURE 7.—*Tapeinosperma cephalophorum* Gillespie: *a*, inflorescence; *b*, seed; *c*, fruit; *d*, flower; *e*, pistil; *f*, placenta with ovules, greatly enlarged; *g*, portion of corolla.

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FIGURE 8.—*Tapeinosperma clavatum* Mez: *a*, fruit; *b*, section through flower; *c*, corolla; *d*, calyx; *e*, placenta with ovules, enlarged.

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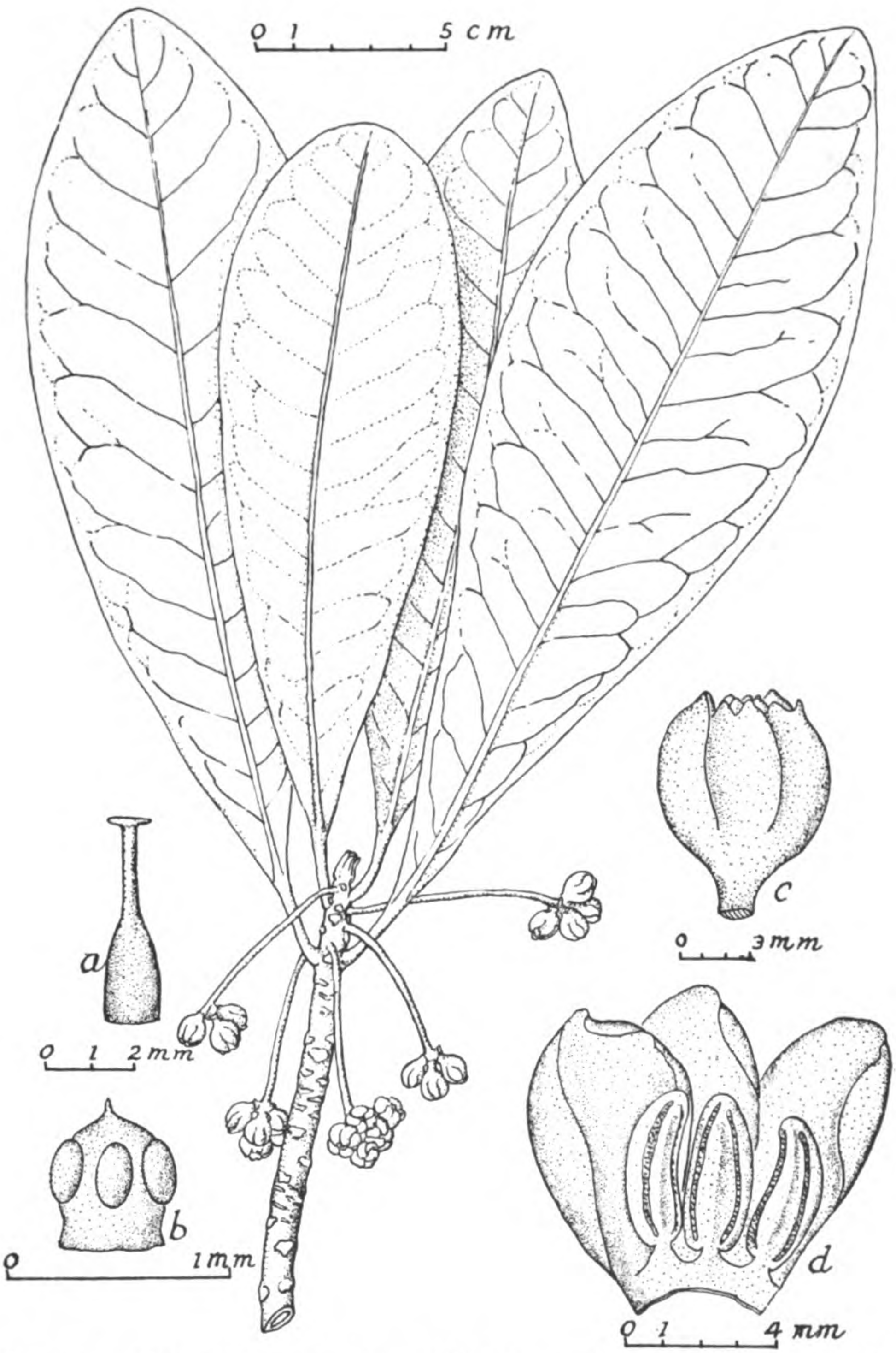

FIGURE 9.—*Tapeinosperma punctatum* Gillespie: *a*, pistil; *b*, placenta with ovules; *c*, flower; *d*, portion of corolla.

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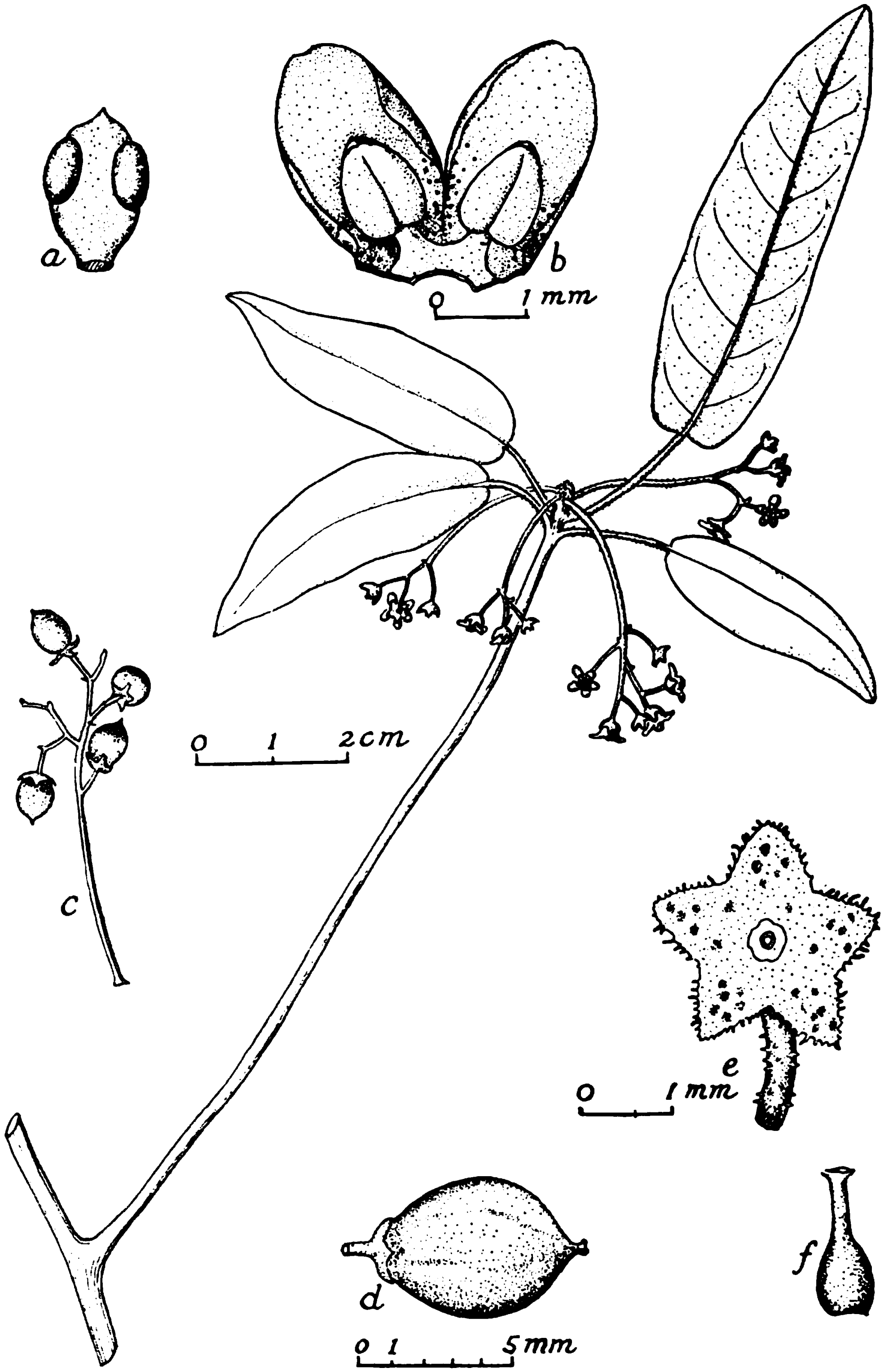

FIGURE 10.—*Discocalyx divaricata* Gillespie: *a*, placenta with ovules; *b*, portion of corolla; *c*, infructescence; *d*, fruit; *e*, calyx; *f*, pistil.

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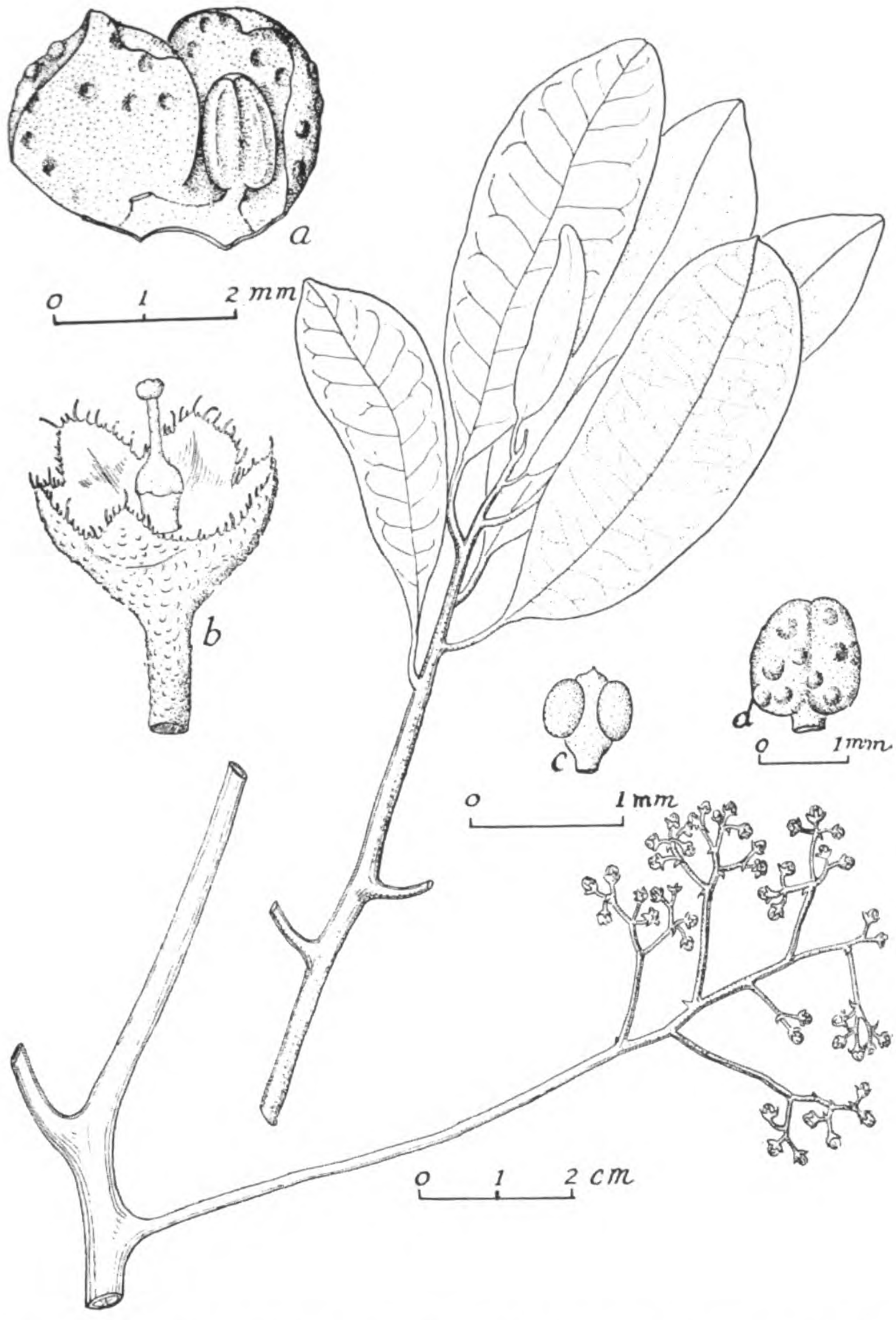

FIGURE 11.—*Discocalyx multiflora* Gillespie: *a*, portion of corolla; *b*, calyx with corolla removed; *c*, placenta with ovules; *d*, adaxile view of anther.

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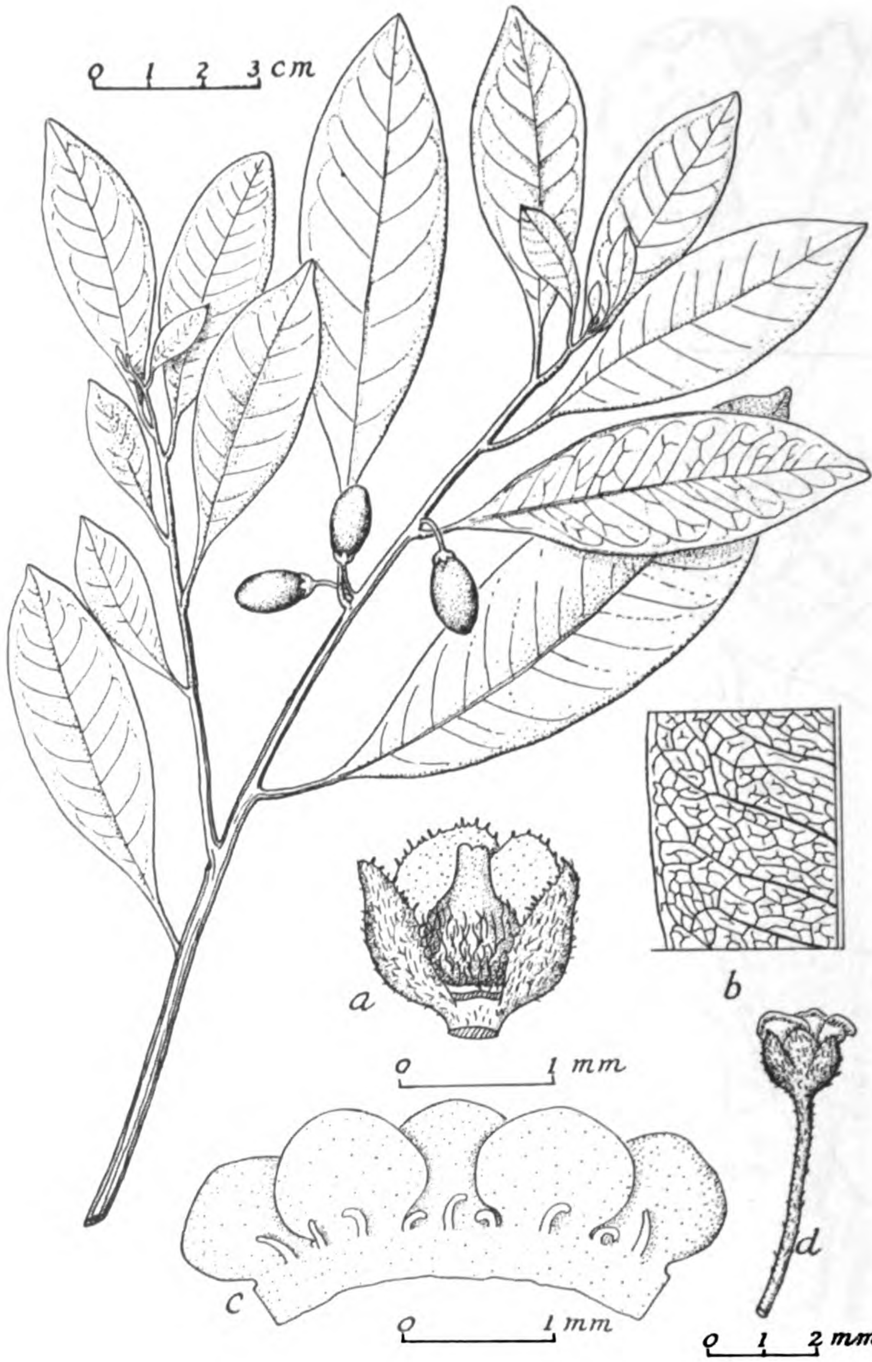

FIGURE 12.—*Planchonella vitiensis* Gillespie: *a*, flower with corolla and one calyx lobe removed; *b*, portion of leaf, enlarged; *c*, corolla; *d*, flower.

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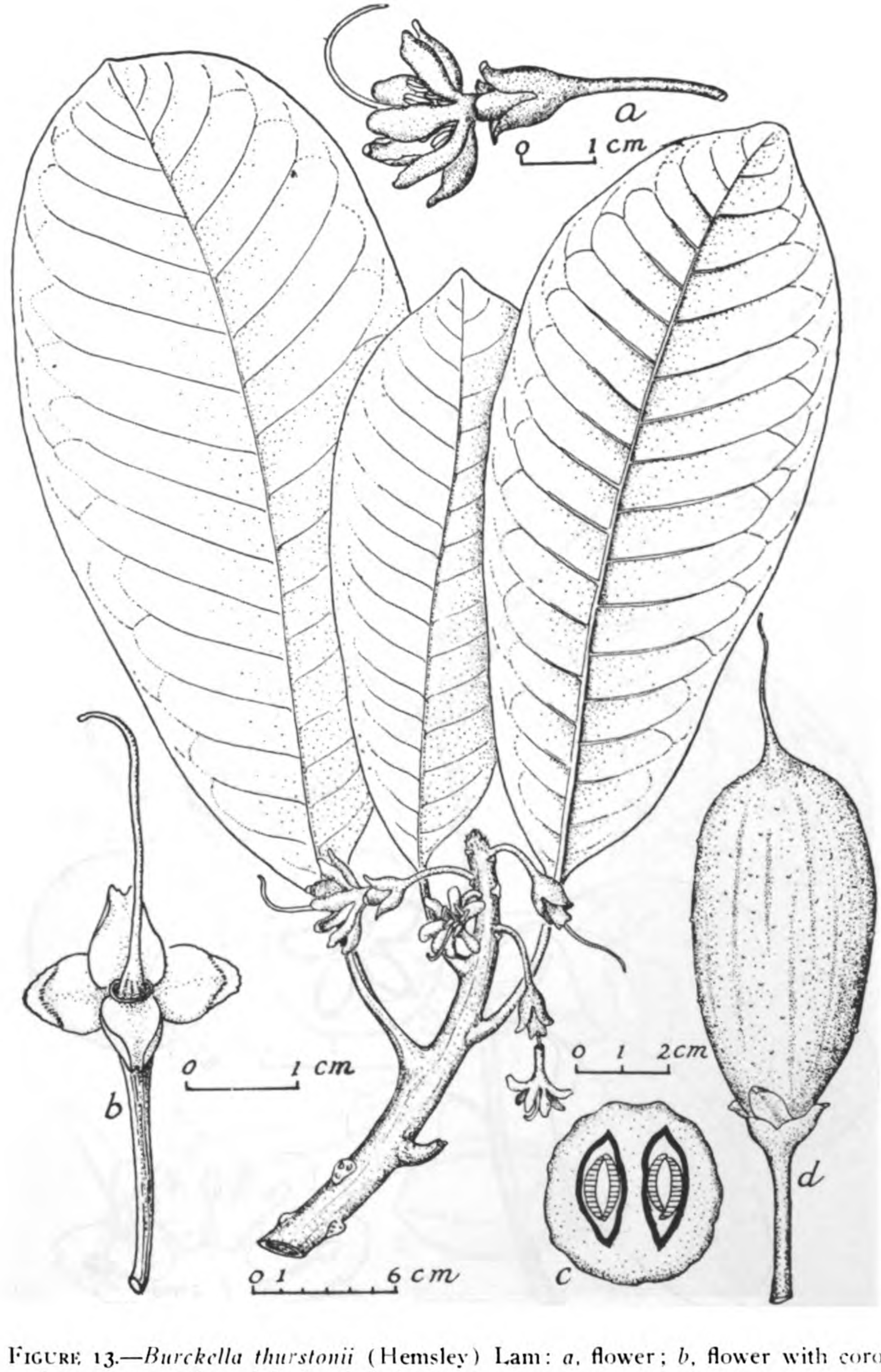

FIGURE 13.—*Burckella thurstonii* (Hemsley) Lam: *a*, flower; *b*, flower with corolla removed; *c*, cross section of fruit; *d*, fruit.

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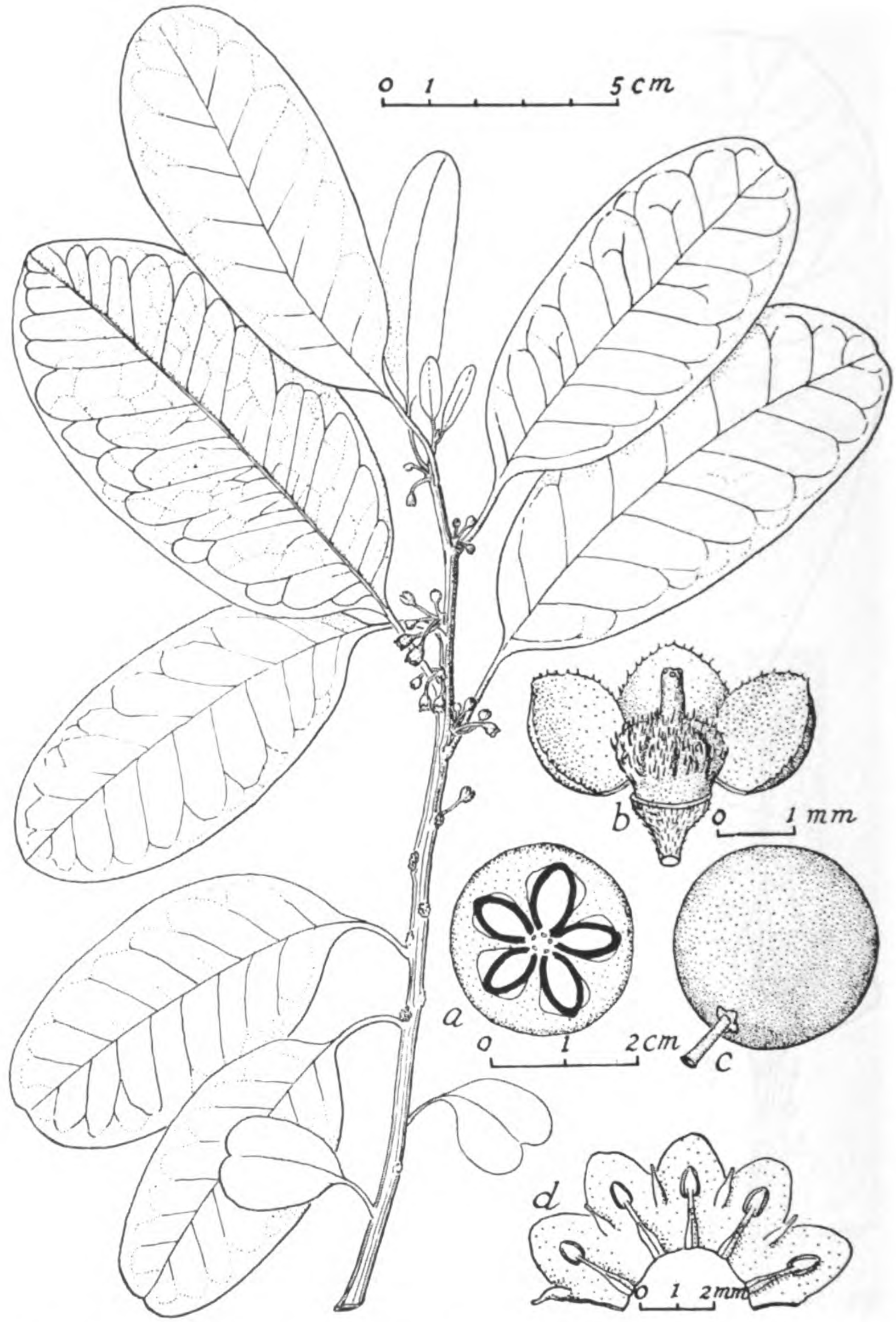

FIGURE 14.—*Lucuma vitiensis* (A. Gray) Gillespie: *a*, cross section of fruit; *b*, *calyx* with corolla removed; *c*, fruit; *d*, corolla.

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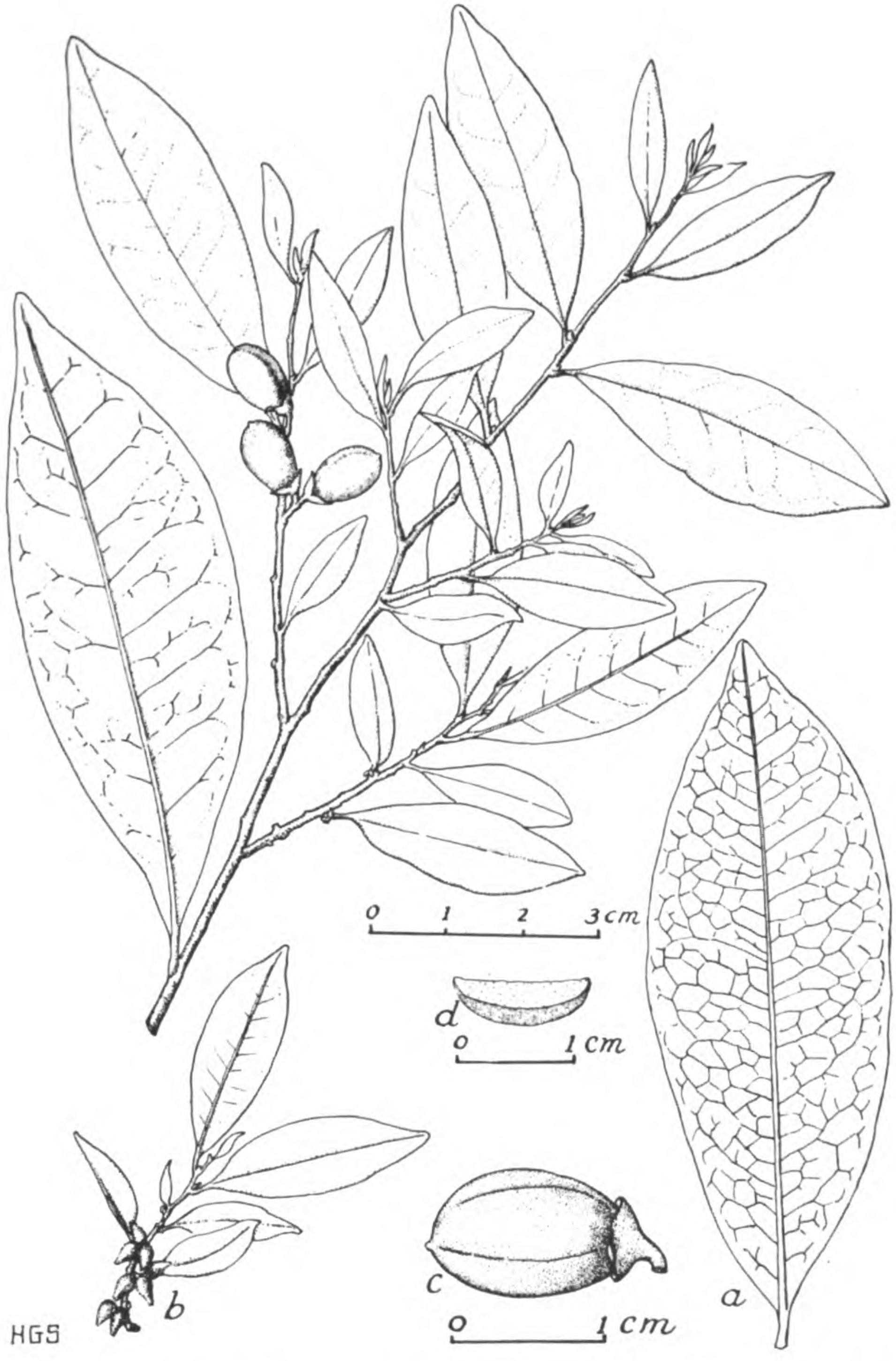

FIGURE 15.—*Maba nandarivatensis* Gillespie: *a*, twig with immature flowers; *b*, seed; *c*, fruit; *d*, leaf showing venation.

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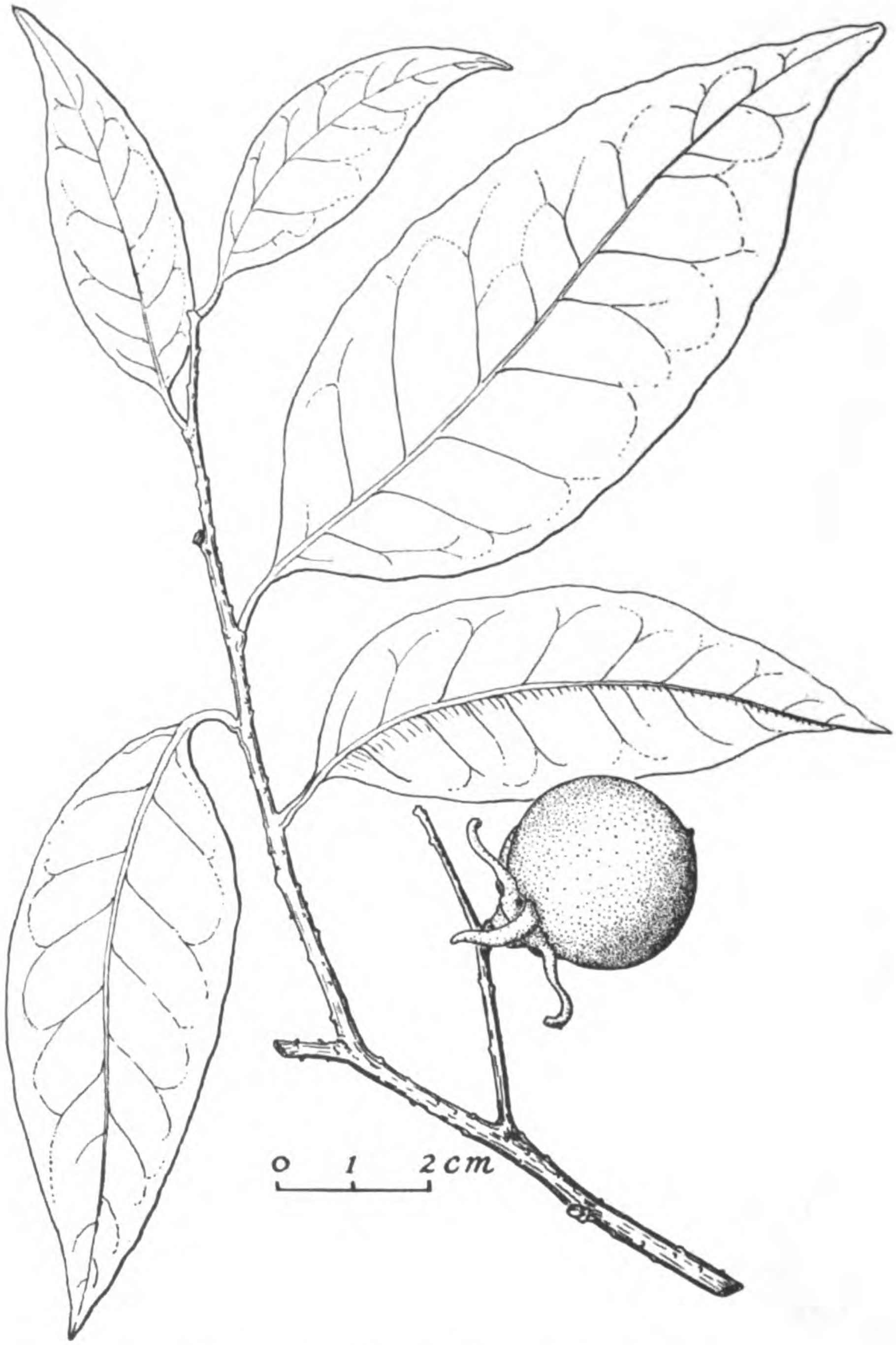

FIGURE 16.—*Diospyros longisepala* Gillespie.

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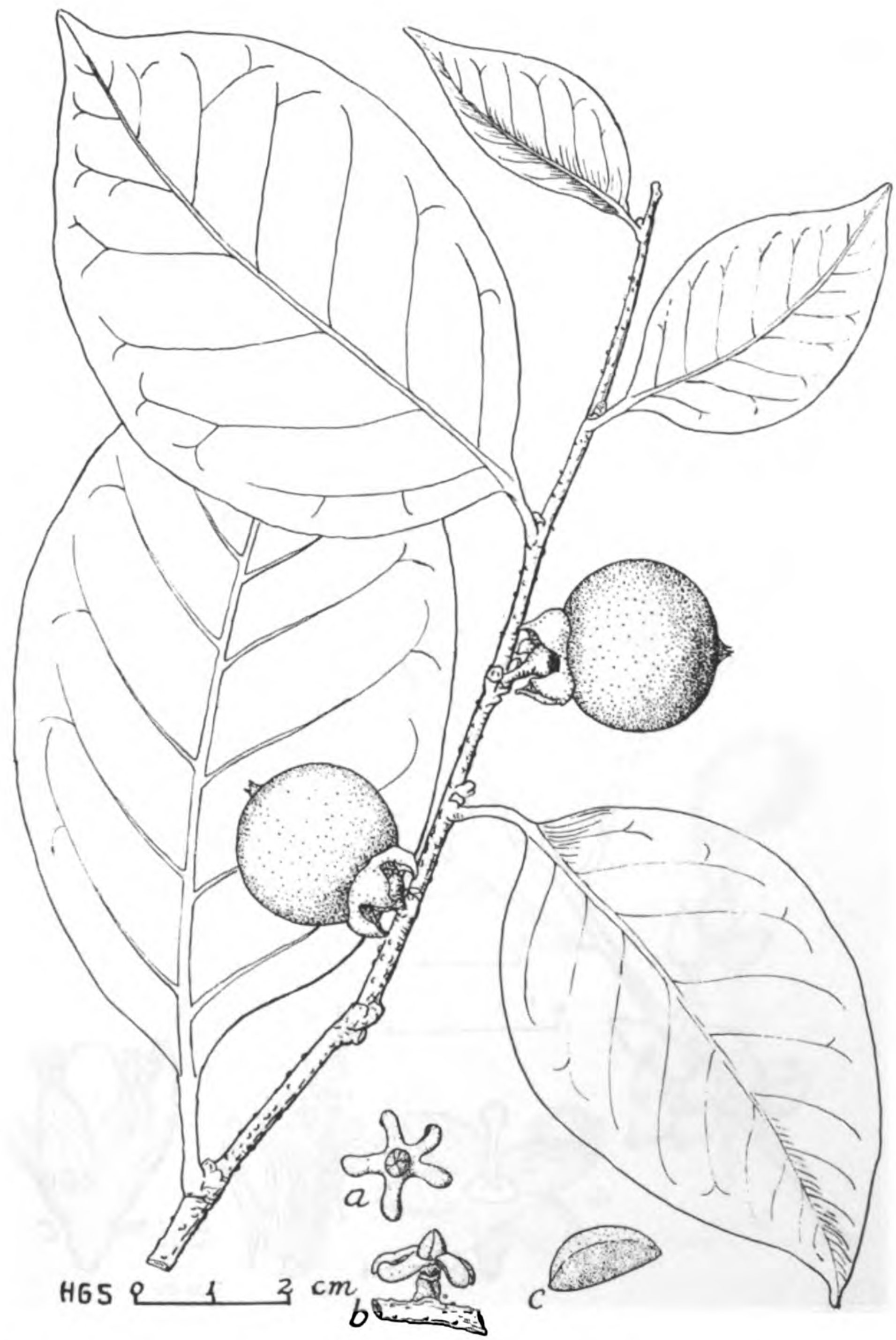

FIGURE 17.—*Diospyros vitiensis* Gillespie: *a*, *b*, female flowers; *c*, seed.

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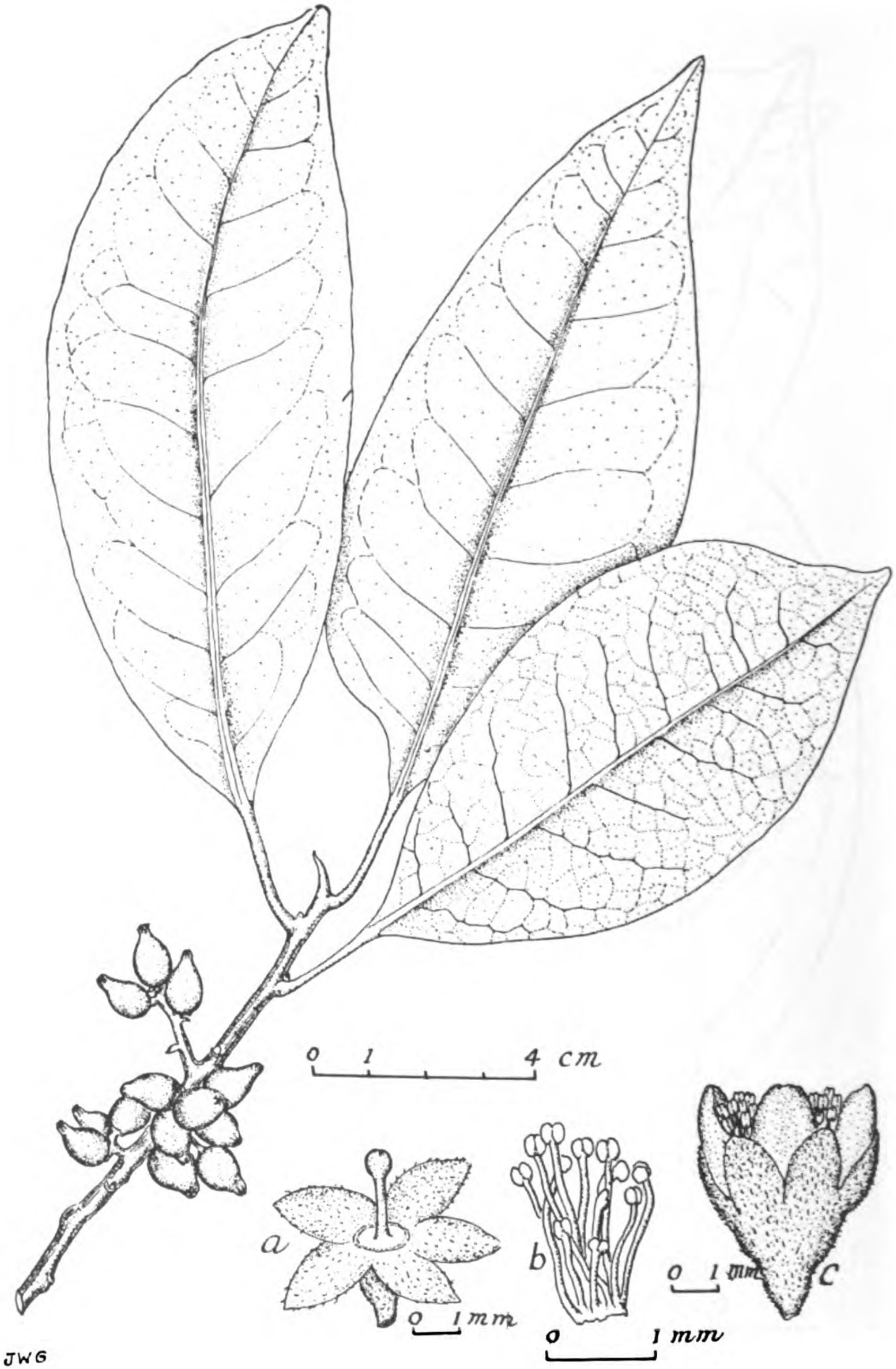

FIGURE 18.—*Symplocos leptophylla* (Brand) Turrill: *a*, flower with corolla removed; *b*, group of stamens; *c*, flower.

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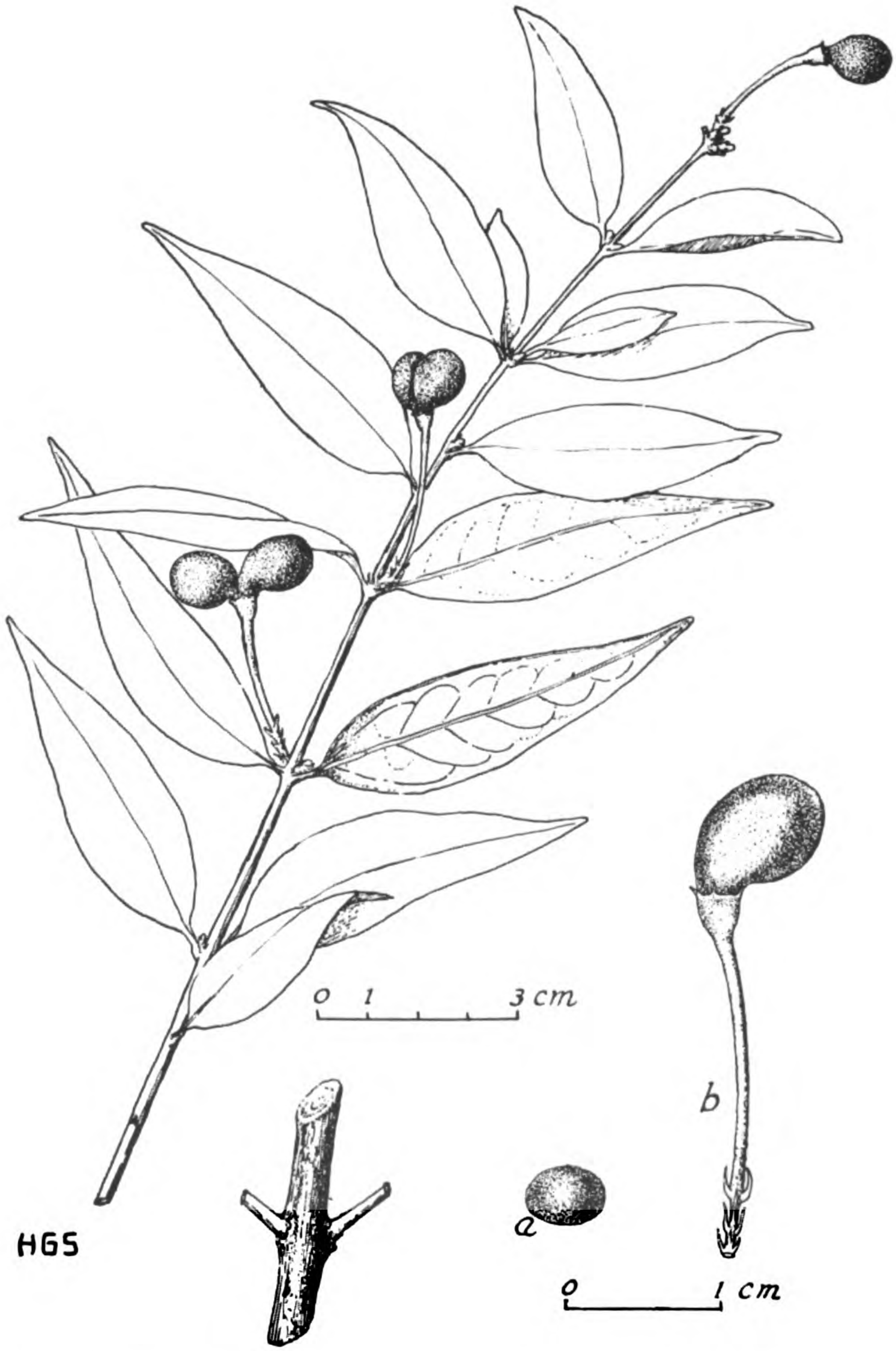

FIGURE 19.—*Jasminum unifoliolatum* Gillespie: *a*, seed; *b*, infructescence.

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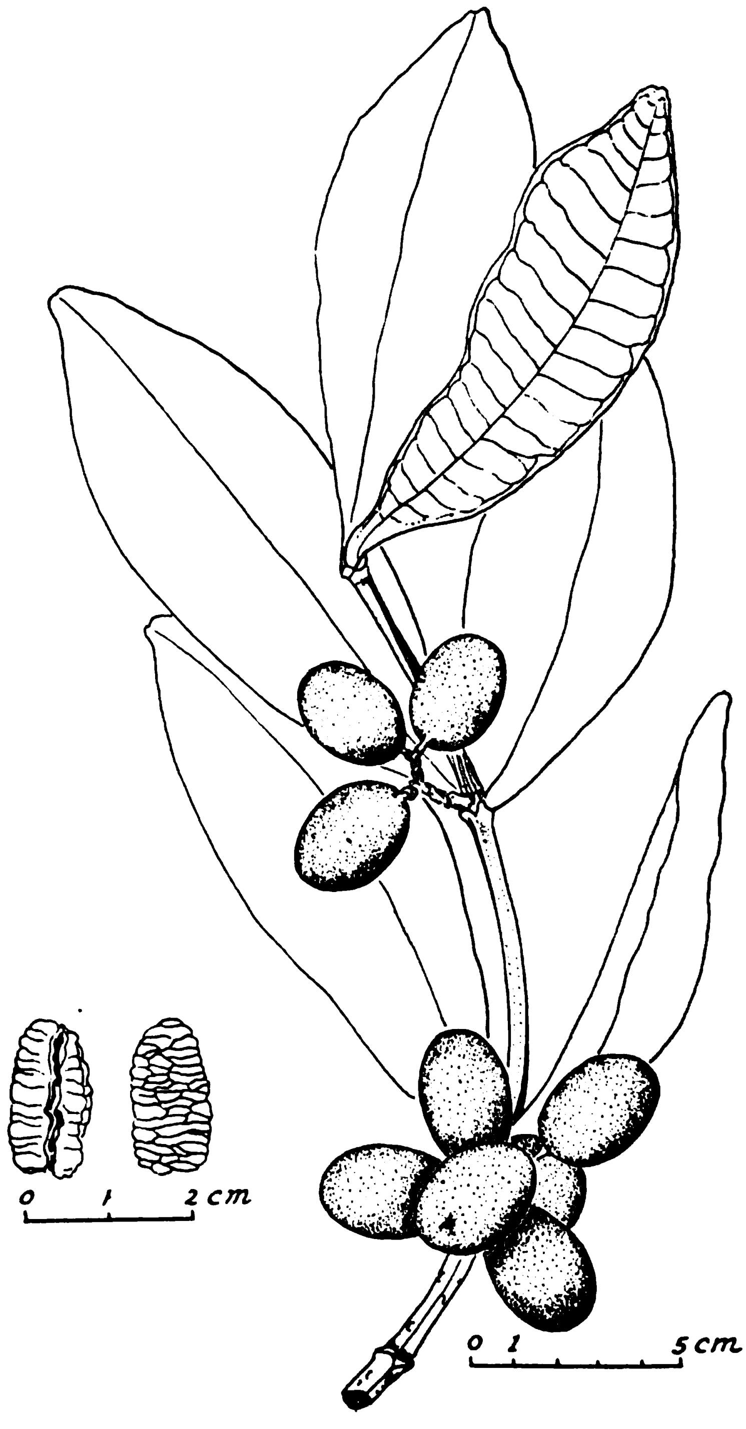

FIGURE 20.—*Alyxia erythrosperma* Gillespie: *a*, *b*, seed.

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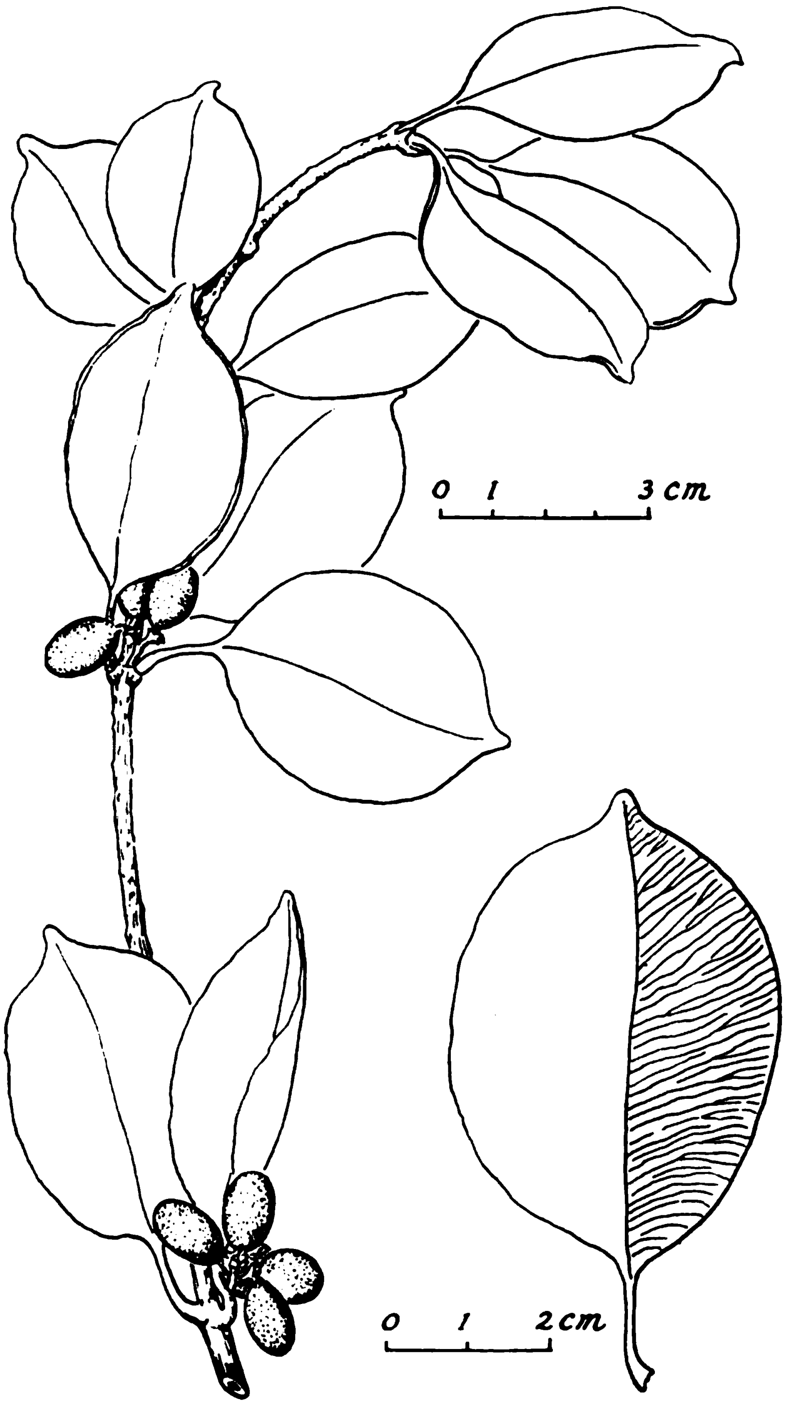

FIGURE 21.—*Alyxia ovalifolia* Gillespie.

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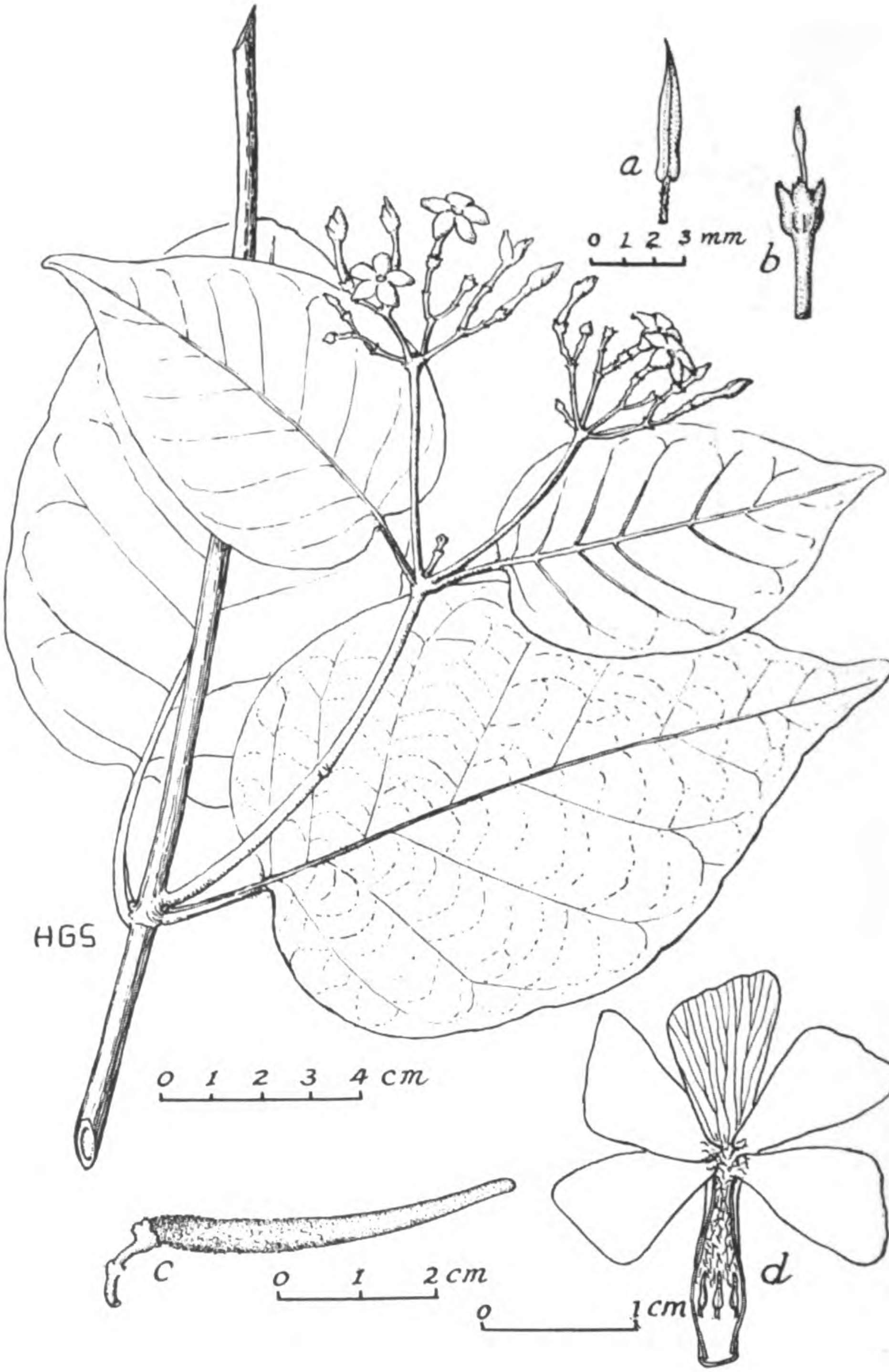

FIGURE 22.—*Carruthersia latifolia* Gillespie: *a*, anther; *b*, calyx with corolla removed; *c*, immature follicle; *d*, corolla split open.

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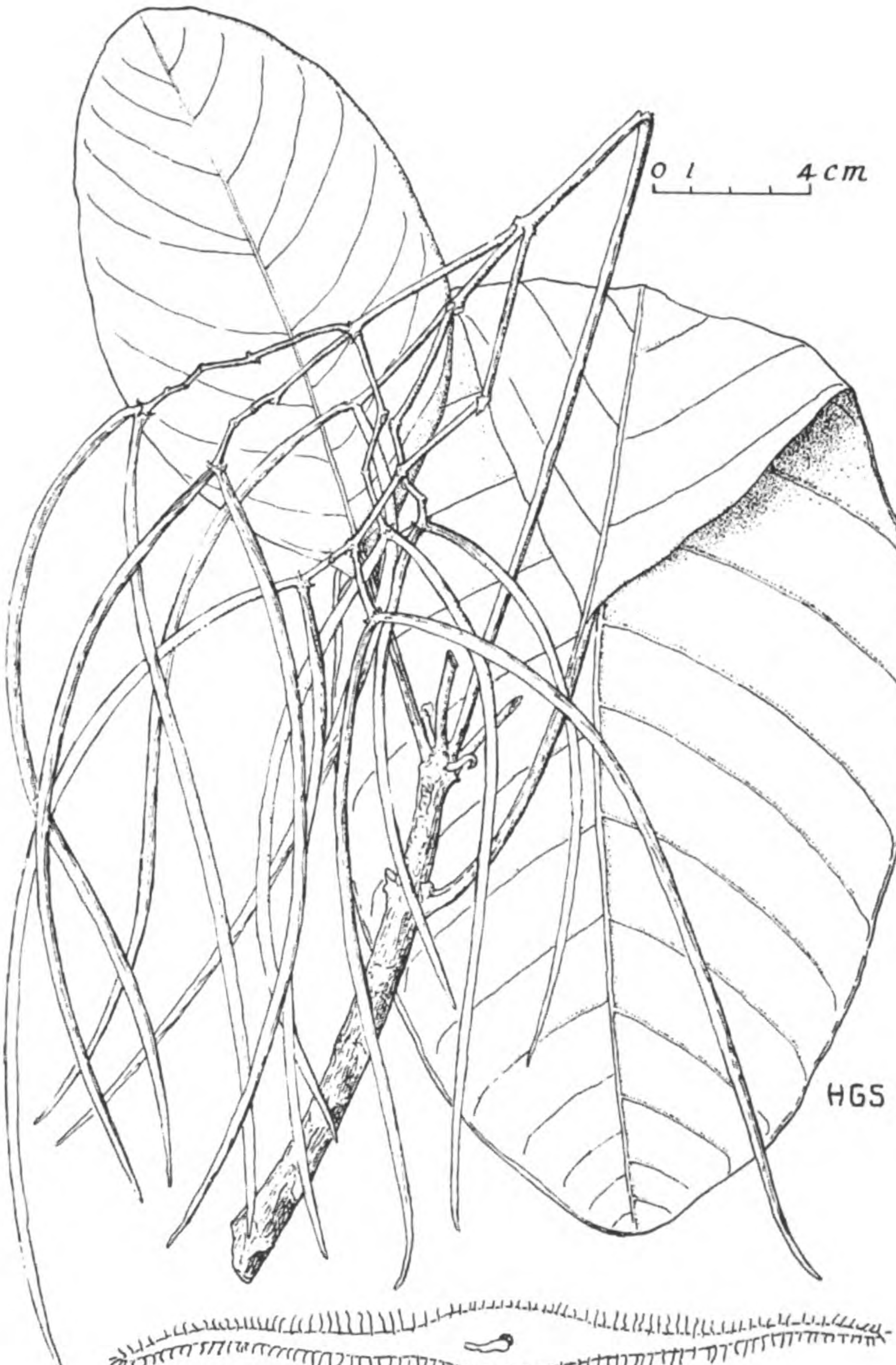

FIGURE 23.—*Alstonia vitiensis* Seemann: *a*, seed.

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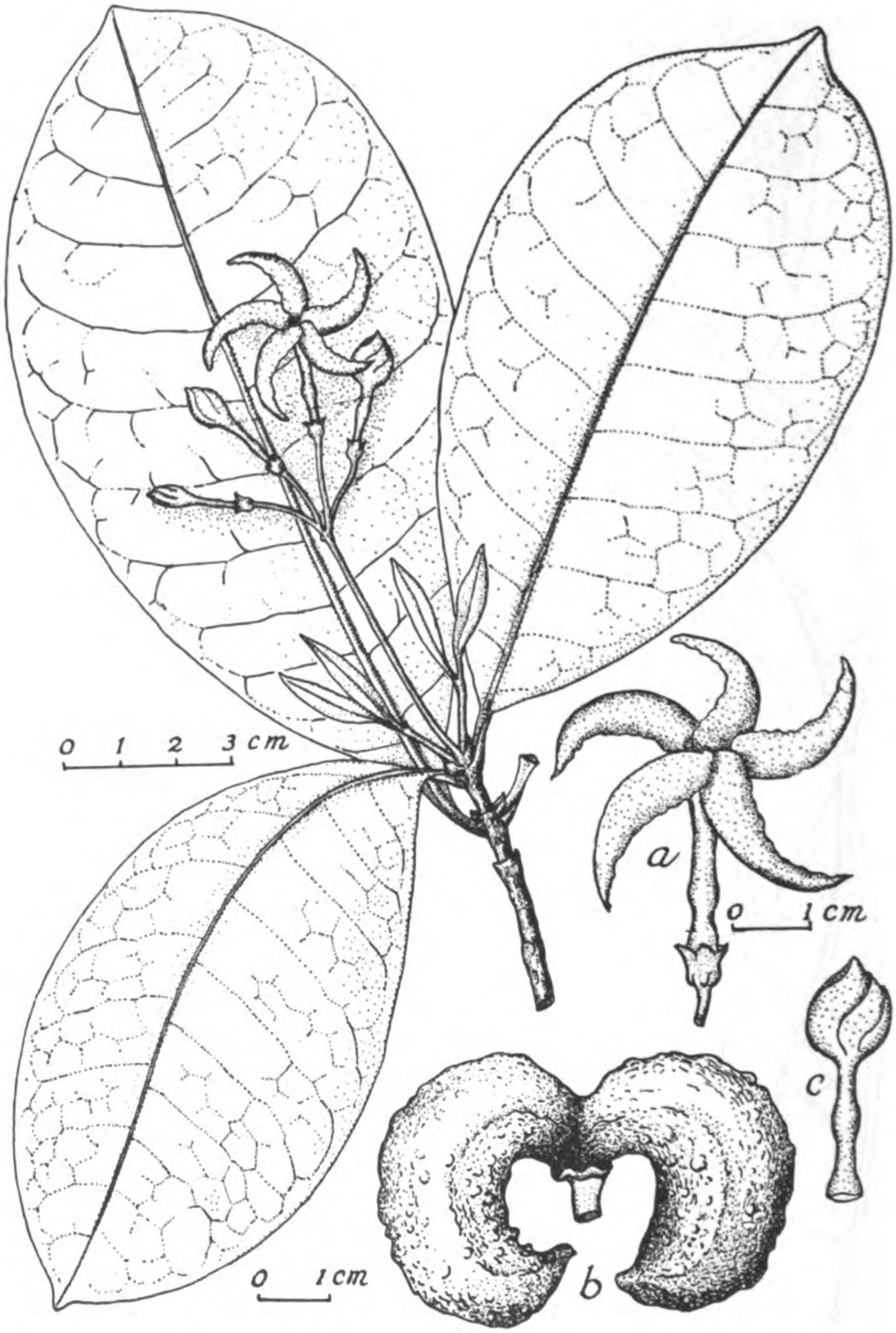

FIGURE 24.—*Tabernaemontana thurstoni* Horne: *a,* flower; *b,* fruit; *c,* bud.

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FIGURE 25.—*Cyrtandra alba* Gillespie.

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FIGURE 26.—*Cyrtandra cephalophora* Gillespie: *a*, flowering peduncle; *b*, flower; *c*, immature fruit; *d*, fruit.

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FIGURE 27.—*Cyrtandra gracilipes* Gillespie: *a, b,* flower; *c,* flower after corolla has fallen; *d,* fruit.

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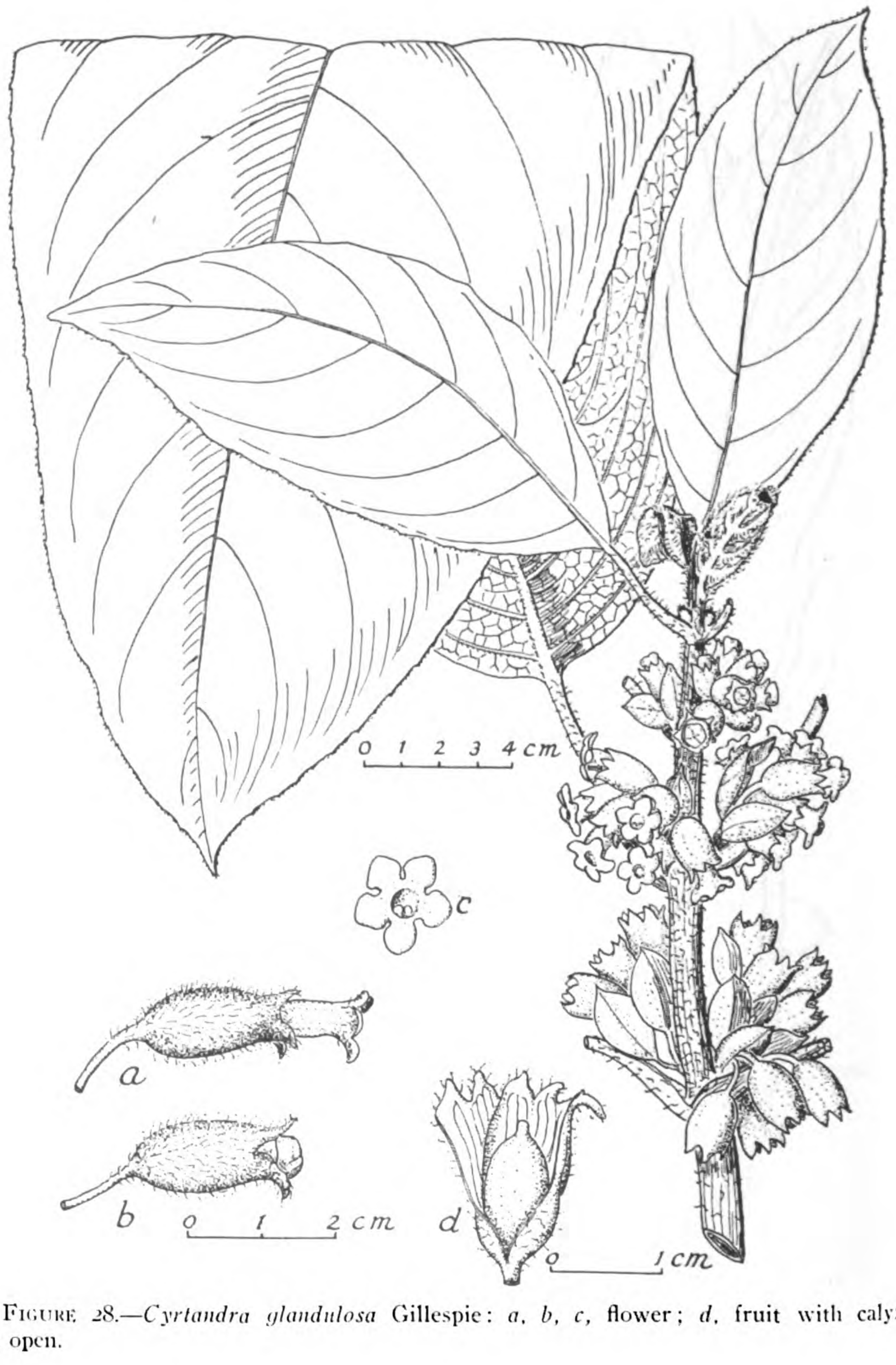

FIGURE 28.—*Cyrtandra glandulosa* Gillespie: *a, b, c,* flower; *d,* fruit with calyx split open.

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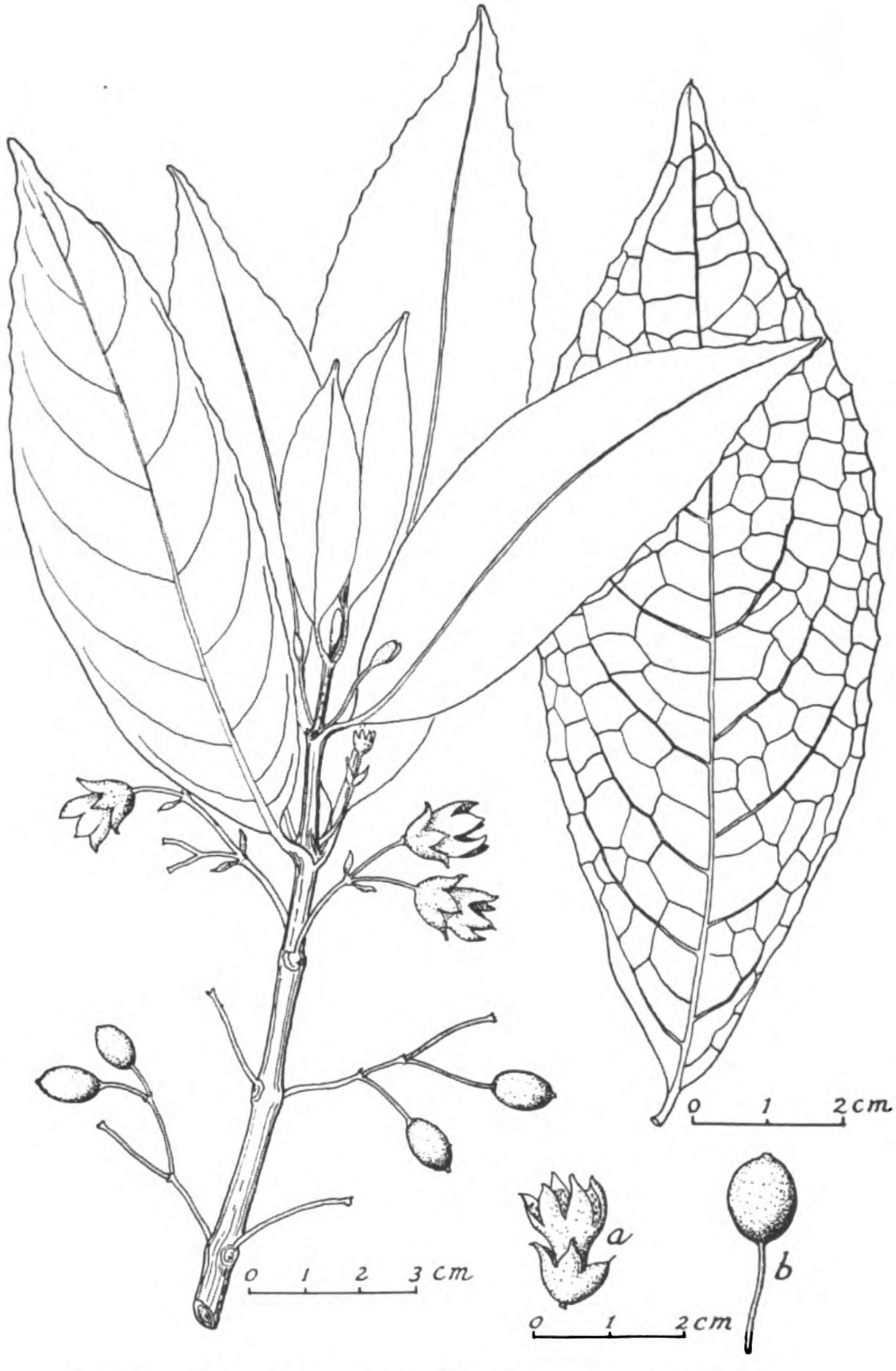

FIGURE 29.—*Cyrtandra montana* Gillespie: *a*, flower; *b*, fruit.

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FIGURE 30.—*Cyrtandra monticola* Gillespie: *a*, flower after corolla has fallen; *b*, fruiting peduncle.

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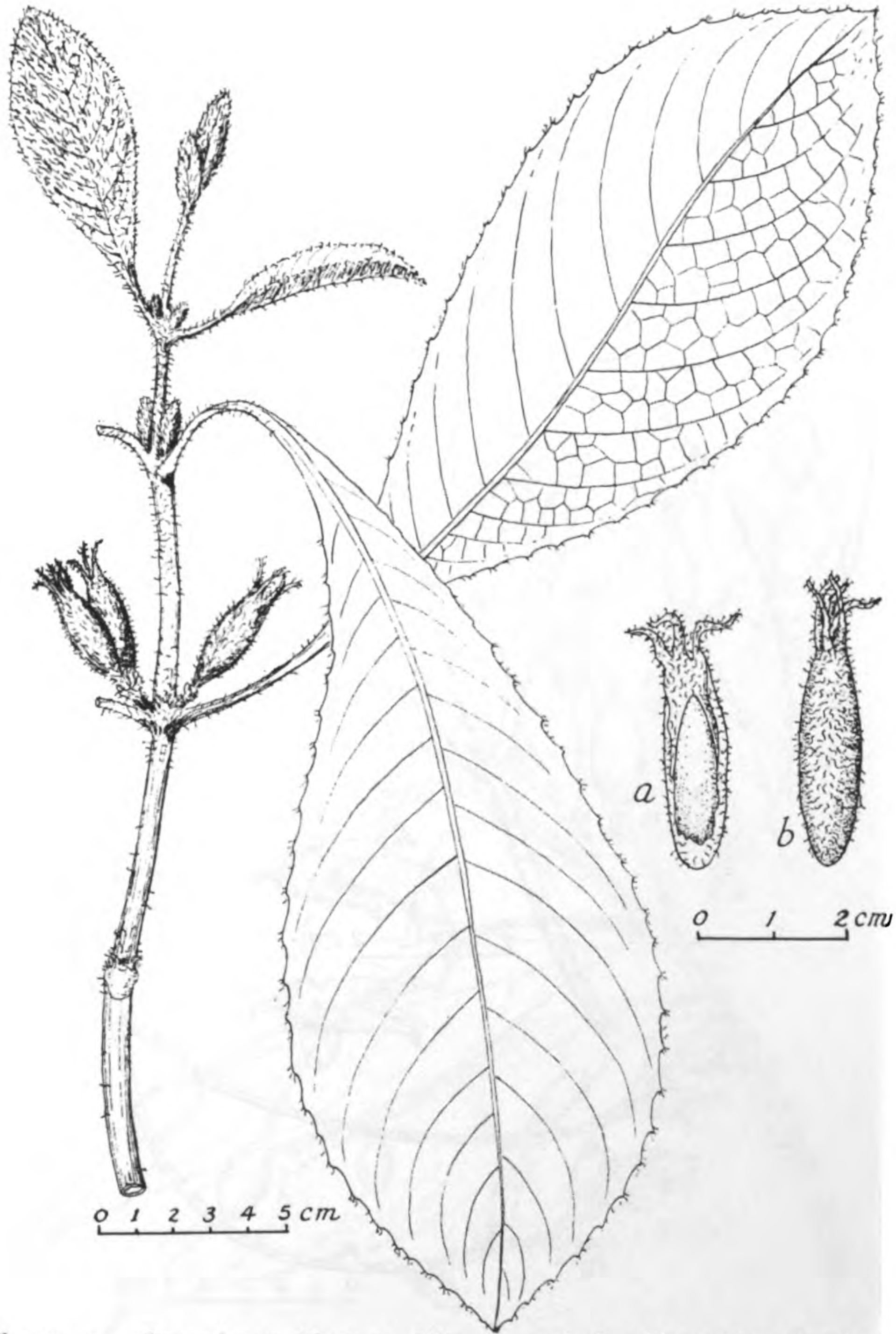

FIGURE 31.—*Cyrtandra multiseptata* Gillespie: *a*, fruit with portion of calyx removed; *b*, fruit.

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FIGURE 32.—*Cyrtandra prattii* Gillespie: *a*, *b*, fruits; *c*, flower; *d*, flower after corolla has fallen.

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FIGURE 33.—*Cyrtandra taviunensis* Gillespie: *a*, flower; *b*, fruit.

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FIGURE 34.—*Cyrtandra victoriae* Gillespie: *a*, fruit; *b*, flower; *c*, corolla laid open.

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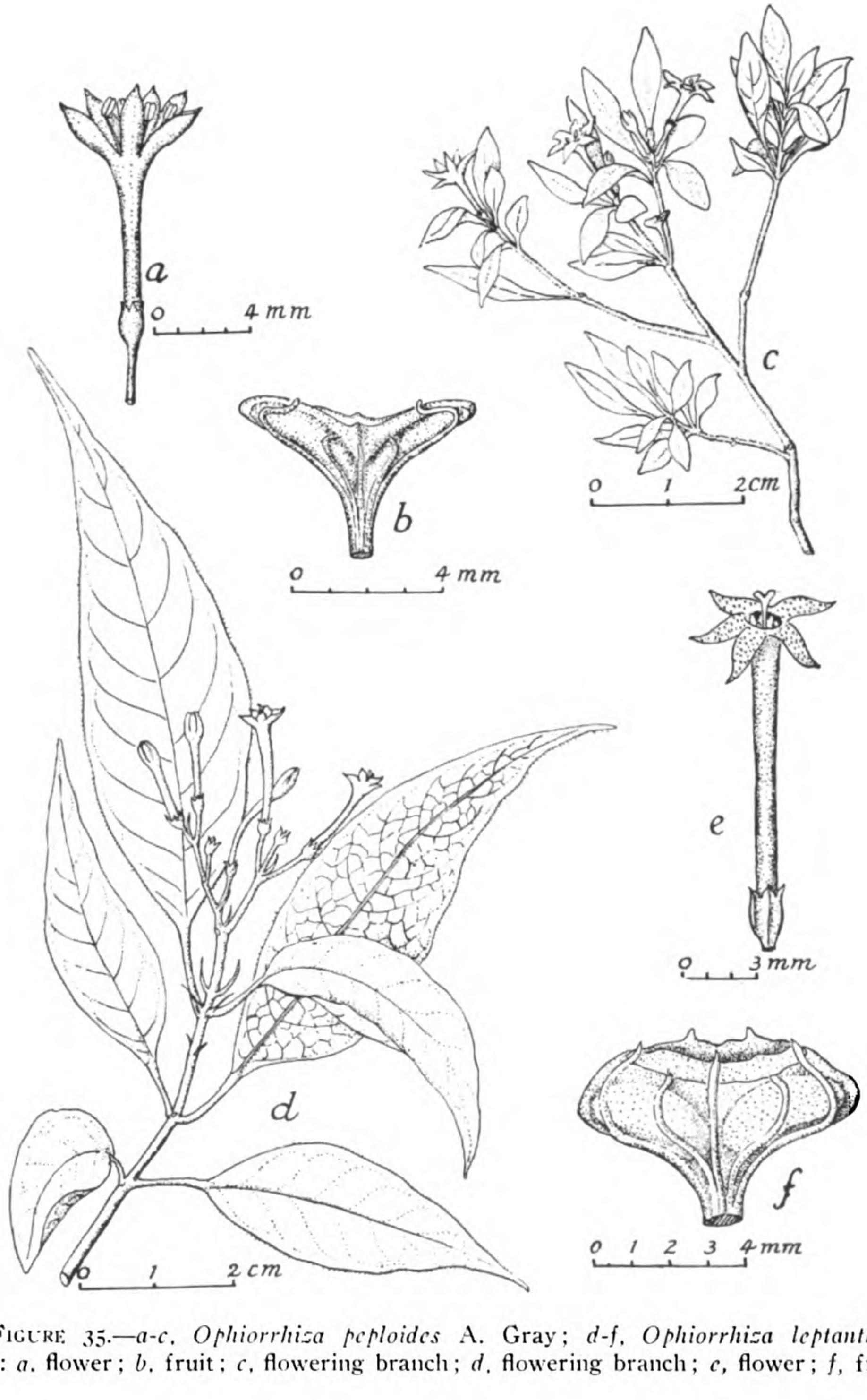

FIGURE 35.—*a-c*, *Ophiorrhiza peploides* A. Gray; *d-f*, *Ophiorrhiza leptantha* A. Gray: *a*, flower; *b*, fruit; *c*, flowering branch; *d*, flowering branch; *e*, flower; *f*, fruit.

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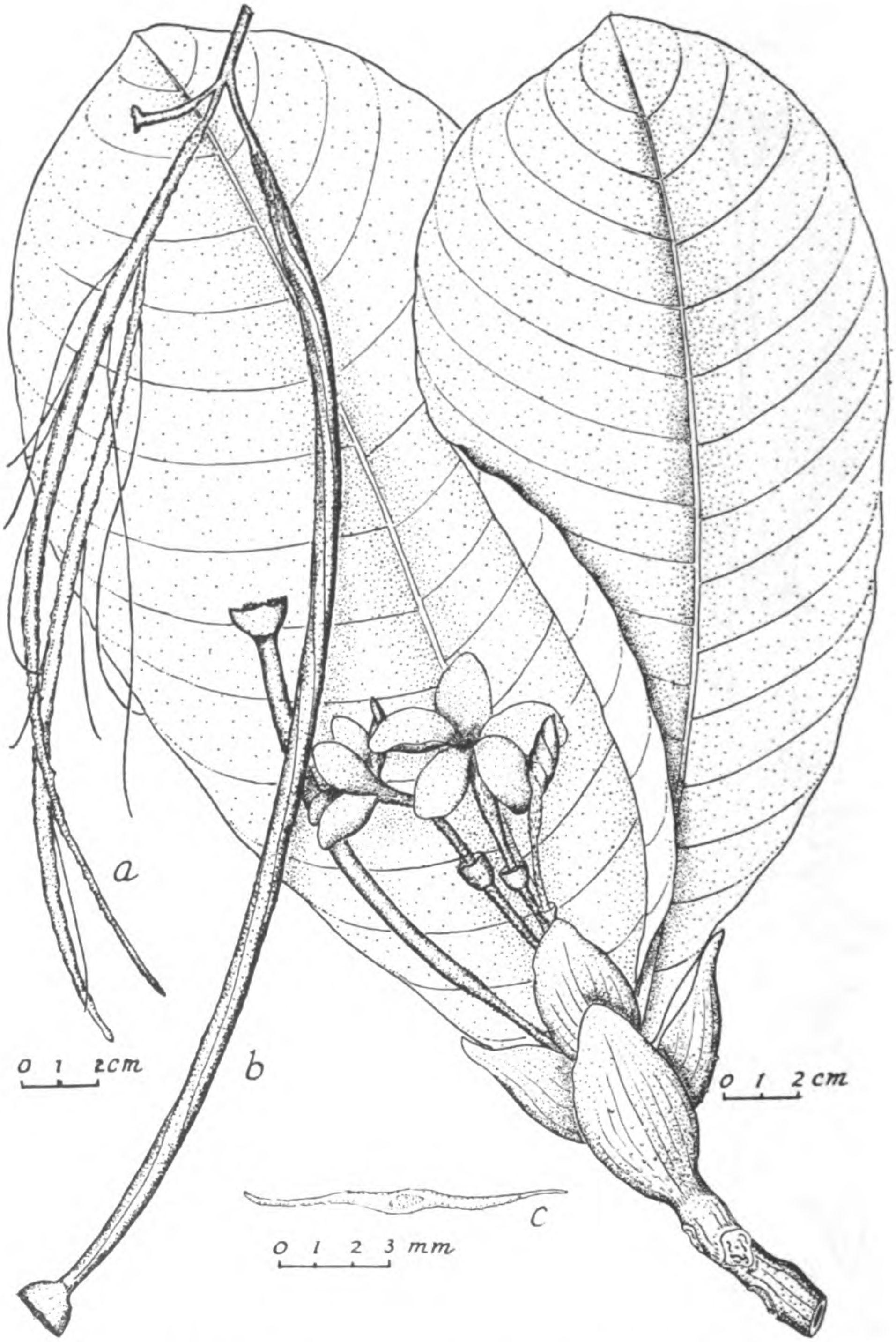

FIGURE 36.—*Dolicholobium macgregori* Horne: *a*, fruit after seeds have fallen; *b*, mature fruit; *c*, seed.

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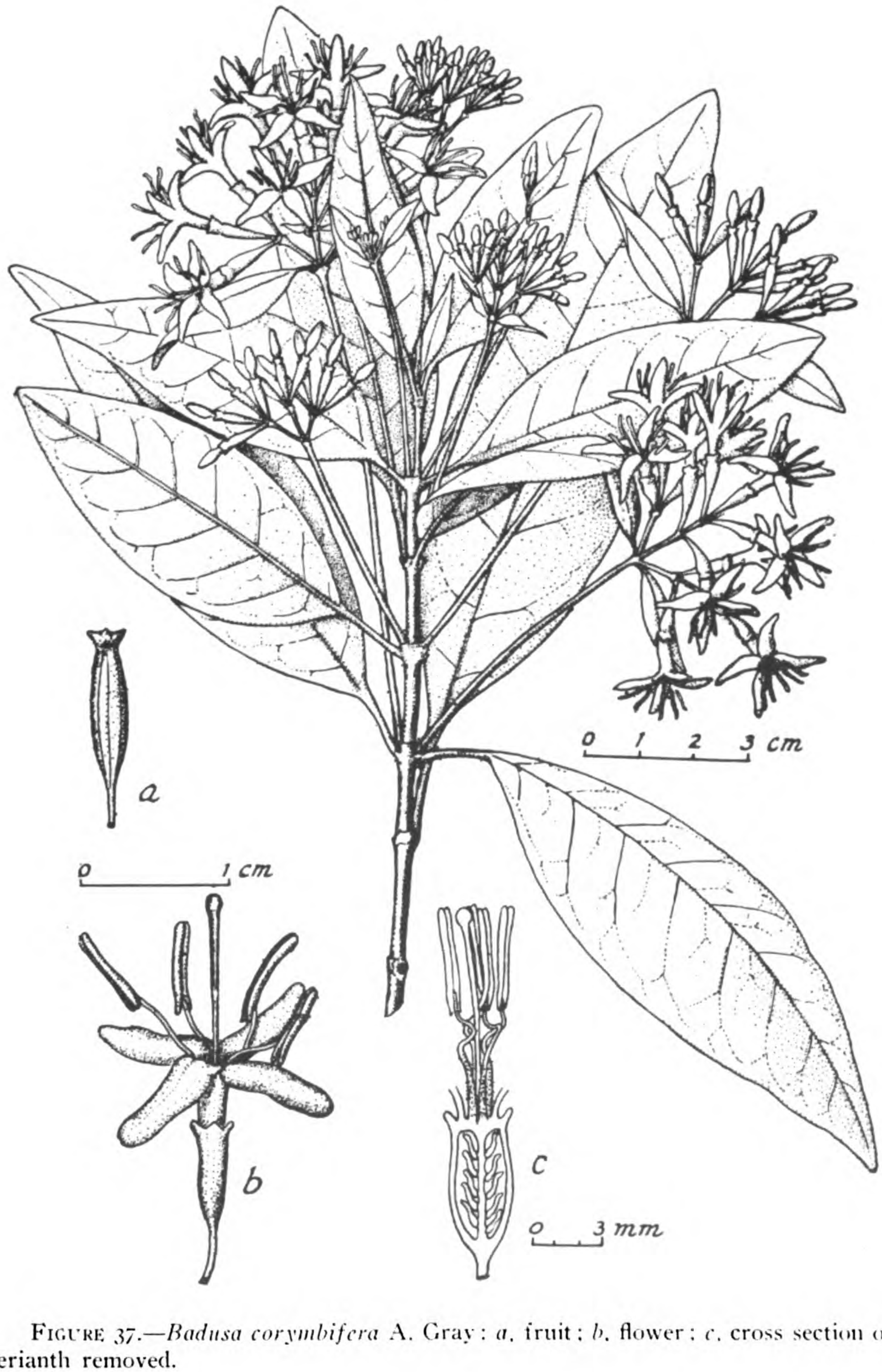

FIGURE 37.—*Badusa corymbifera* A. Gray: *a*, fruit; *b*, flower; *c*, cross section of bud, perianth removed.

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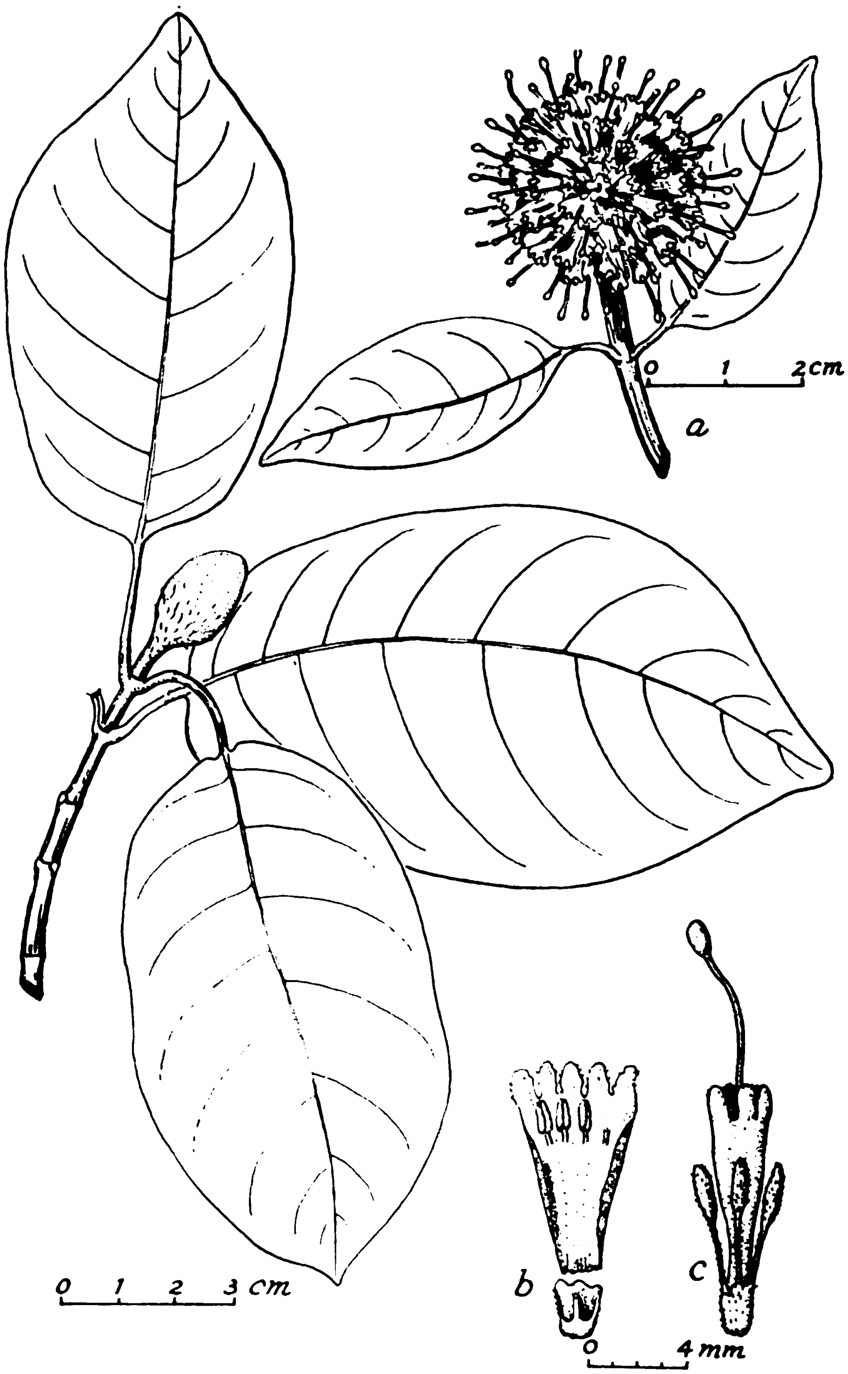

FIGURE 38.—*Neonauclea vitiensis* Gillespie: *a*, cluster of flowers; *b*, portion of corolla; *c*, flower.

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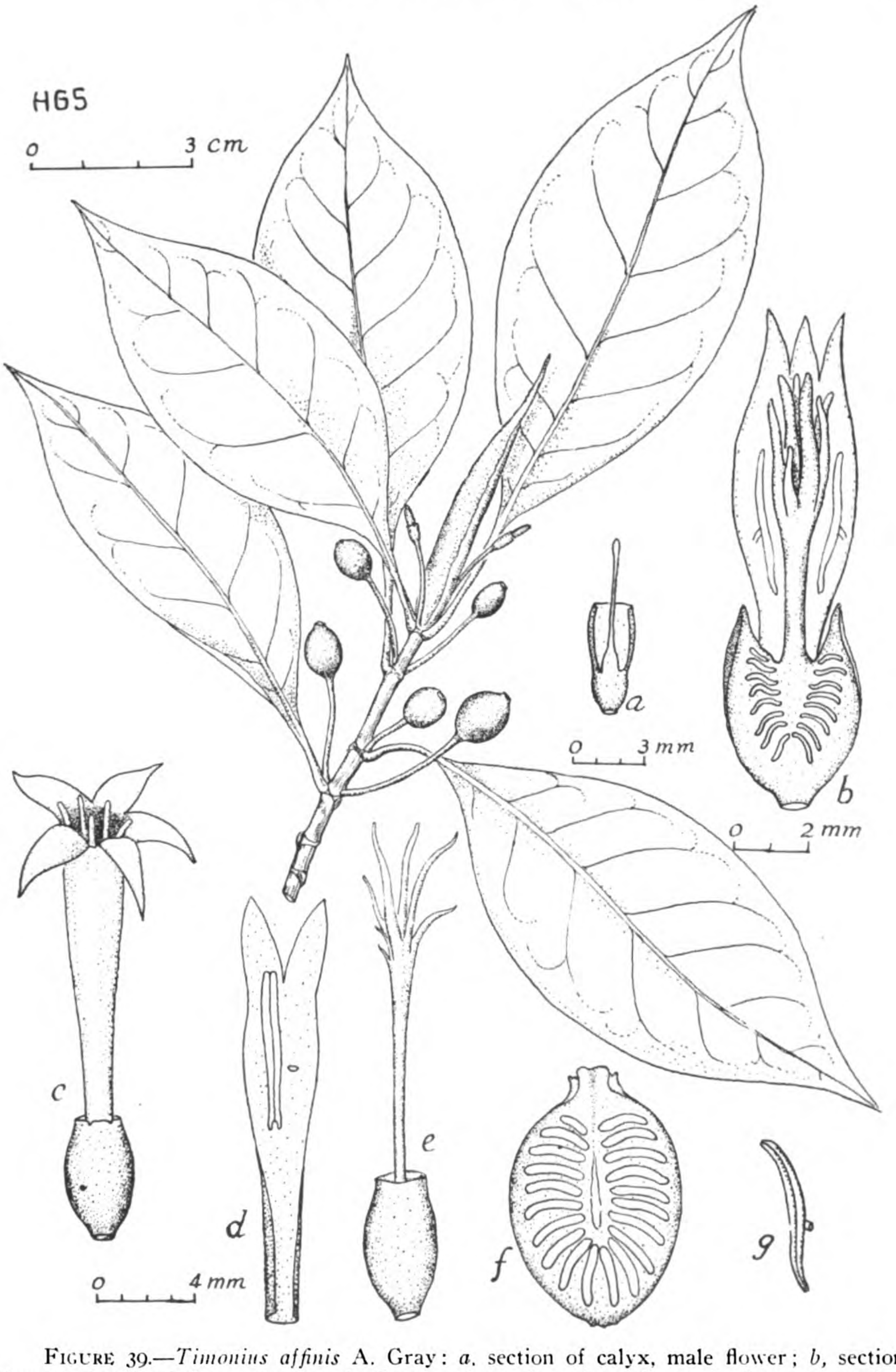

FIGURE 39.—*Timonius affinis* A. Gray: *a*, section of calyx, male flower; *b*, section through fertilized flower; *c*, female flower; *d*, portion of corolla, male flower; *e*, calyx with corolla removed, female flower; *f*, section through fruit; *g*, anther, male flower.

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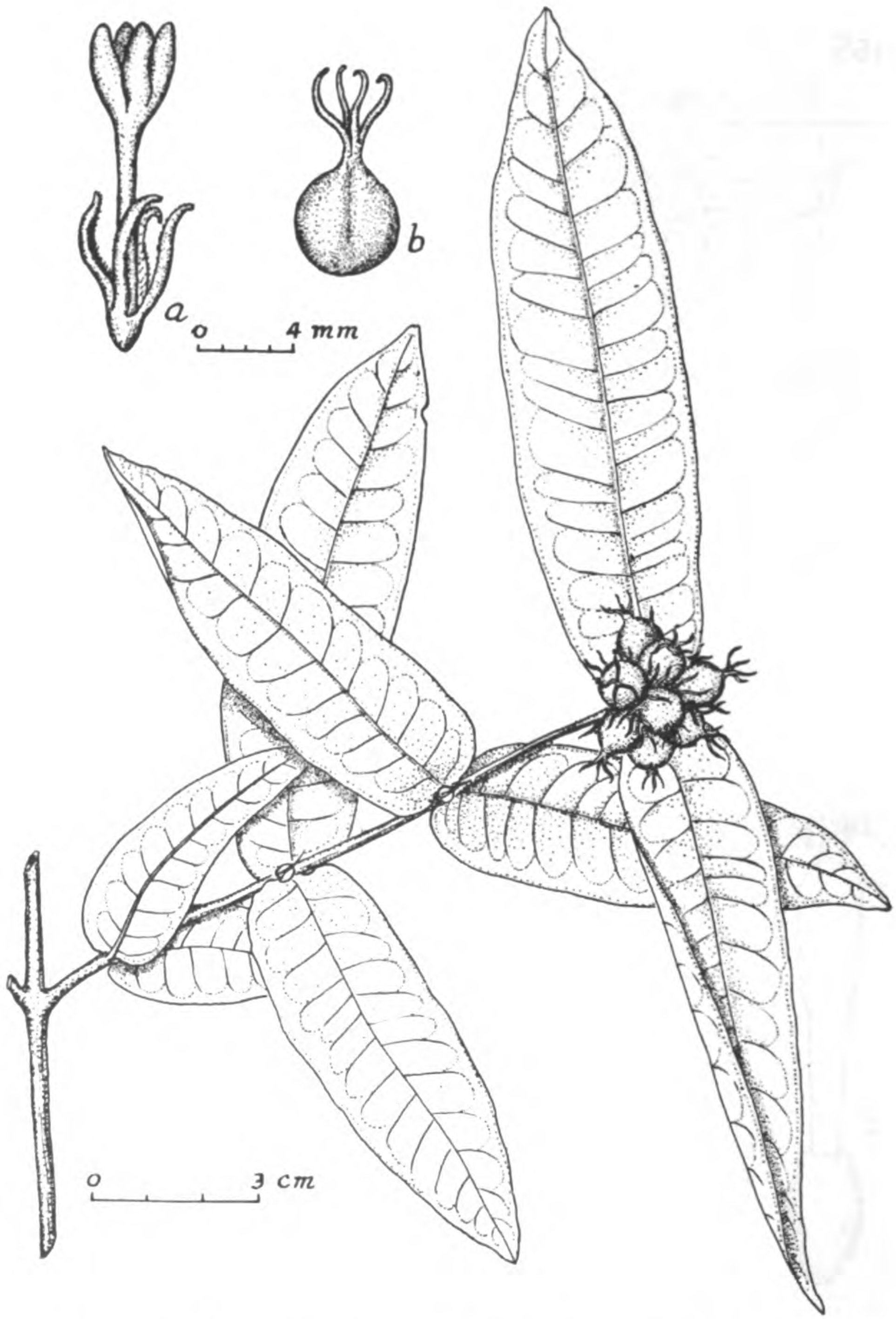

FIGURE 40.—*Ixora amplexicaulis* Gillespie: *a*, flower; *b*, fruit.

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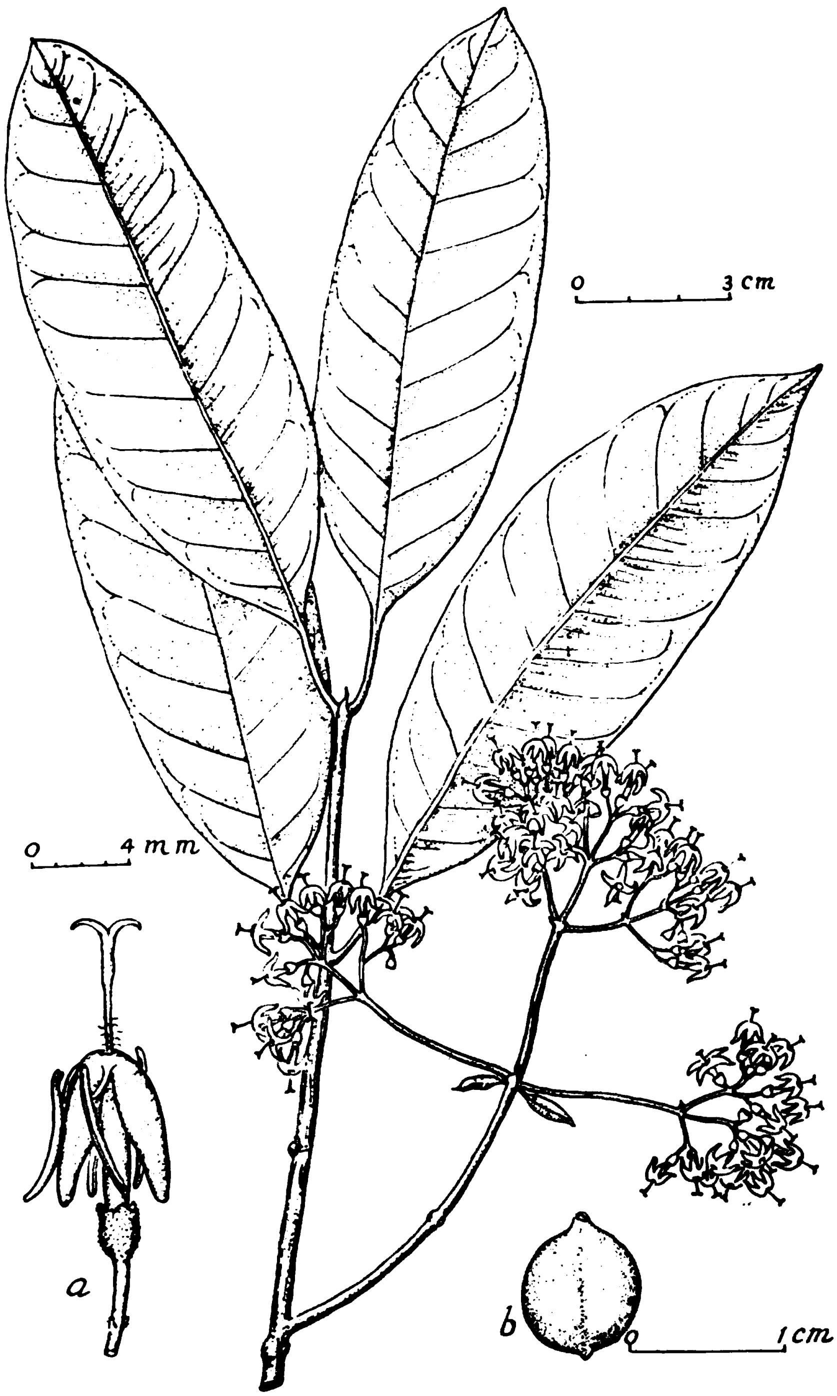

FIGURE 41.—*Ixora elegans* Gillespie: *a*, flower; *b*, fruit.

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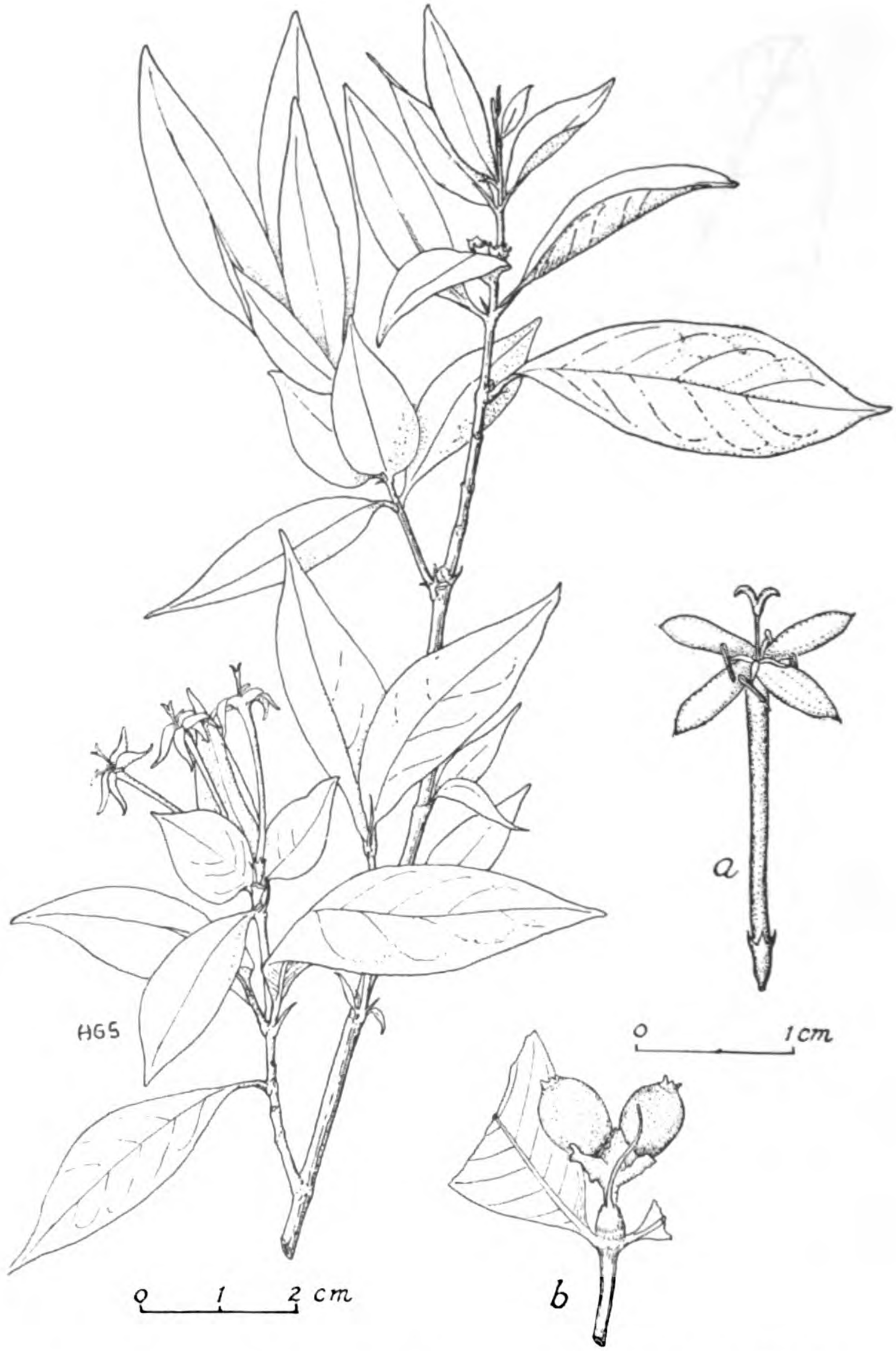

FIGURE 42.—*Ixora nandarivatensis* Gillespie: *a*, flower; *b*, cluster of fruits.

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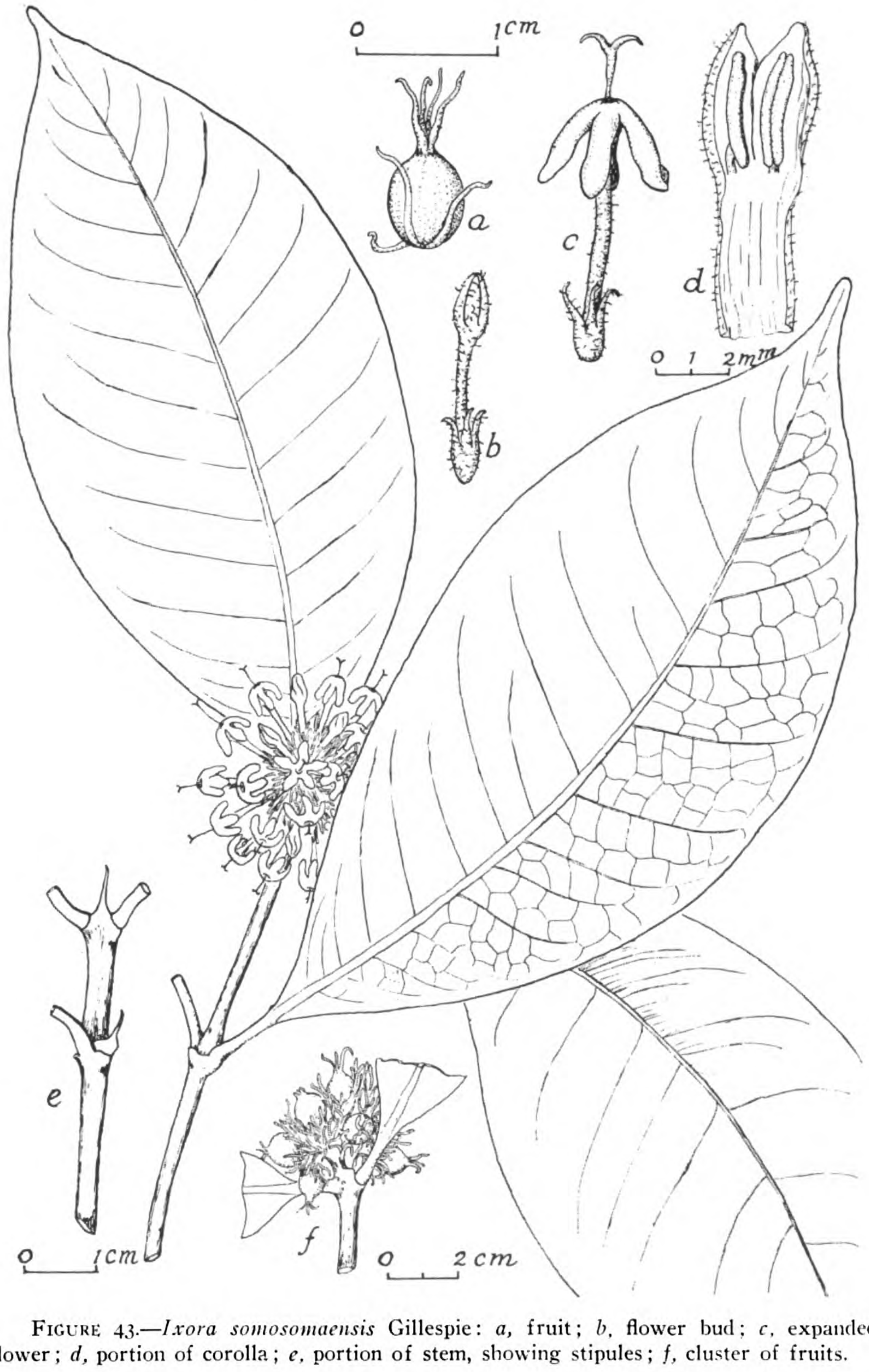

FIGURE 43.—*Ixora somosomaensis* Gillespie: *a*, fruit; *b*, flower bud; *c*, expanded flower; *d*, portion of corolla; *e*, portion of stem, showing stipules; *f*, cluster of fruits.

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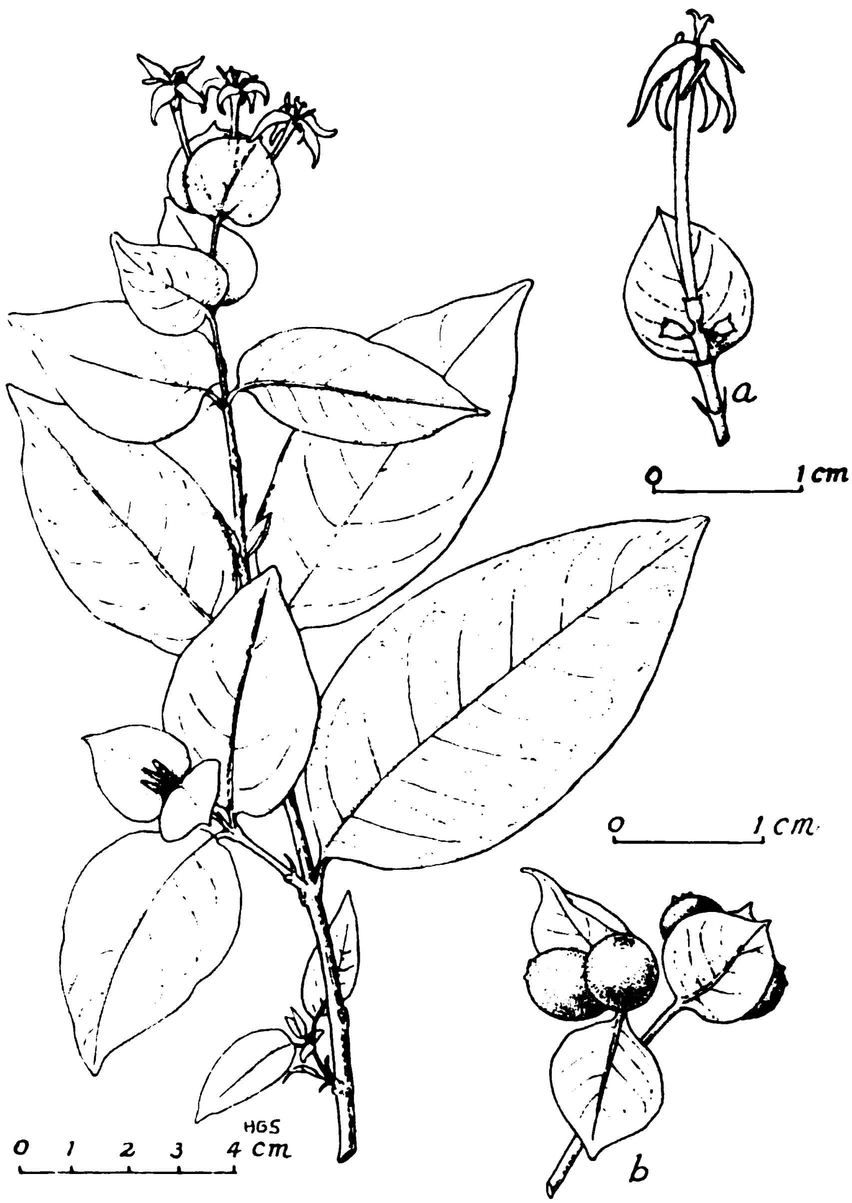

FIGURE 44.—*Ixora vitiensis* A. Gray: *a*, flower; *b*, cluster of fruits.

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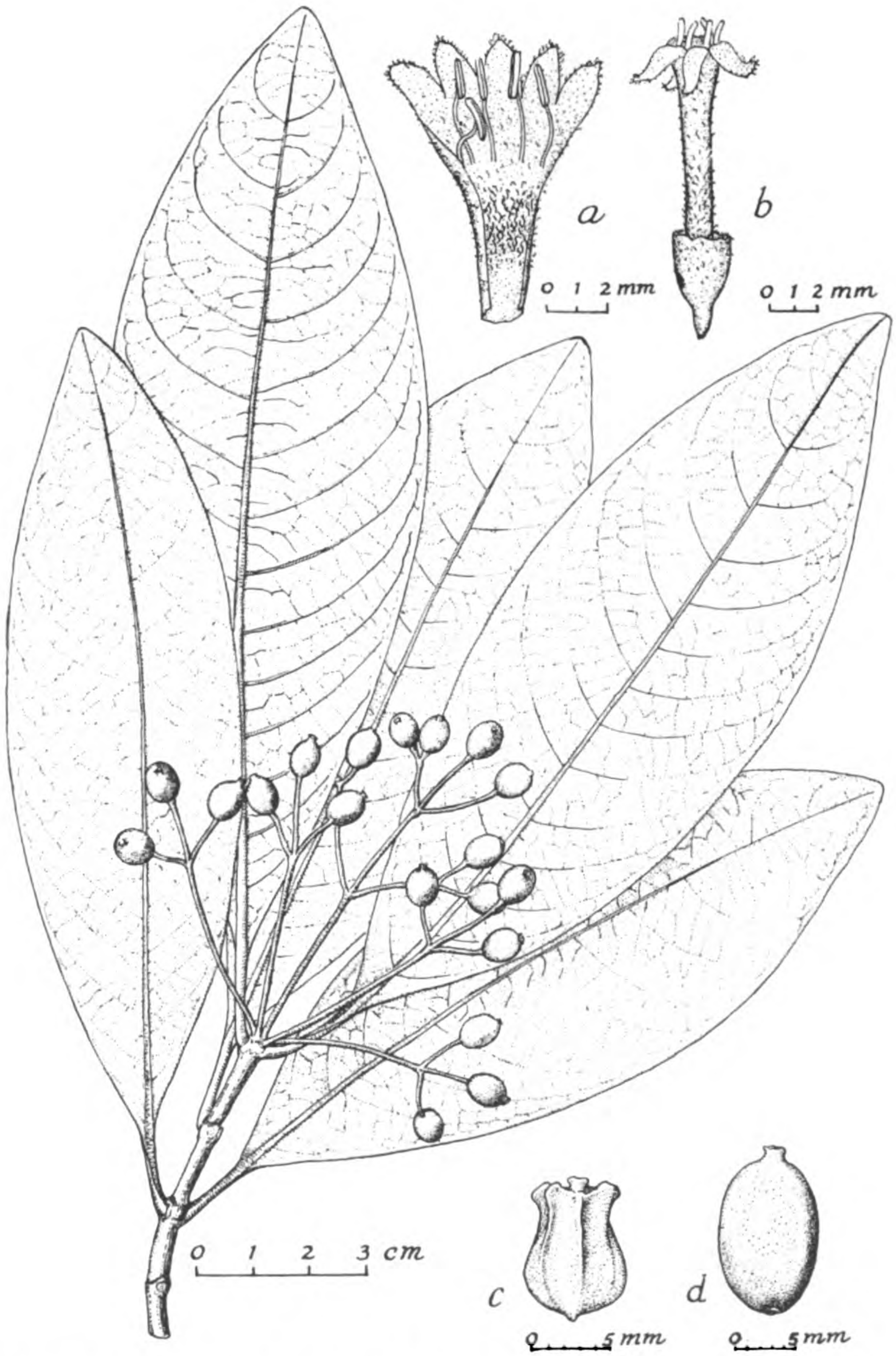

FIGURE 45.—*Psychotria brackenridgii* A. Gray: *a*, corolla; *b*, flower; *c*, seed; *d*, fruit.

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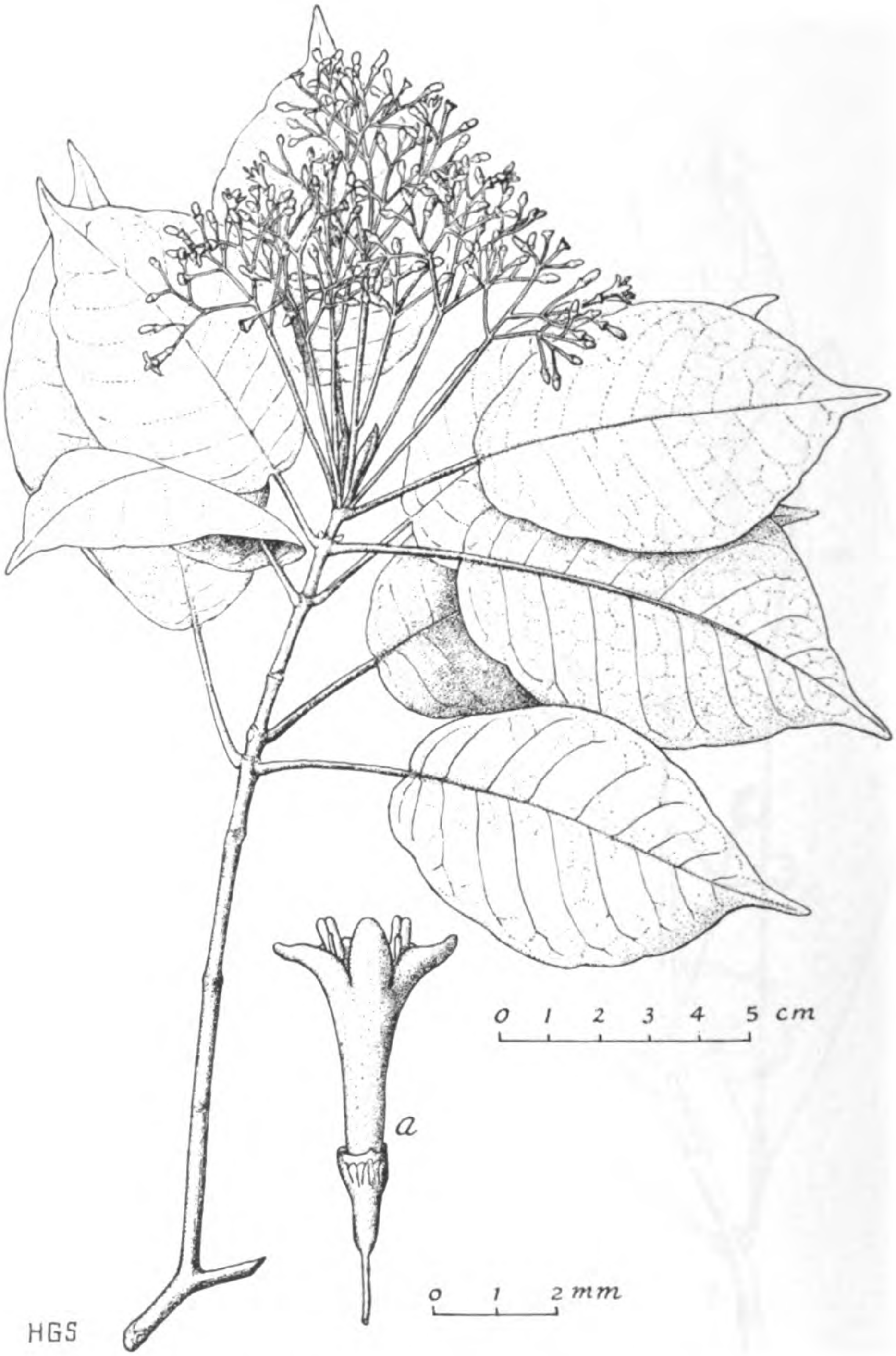

FIGURE 46.—*Psychotria filipes* A. Gray: *a*, flower.

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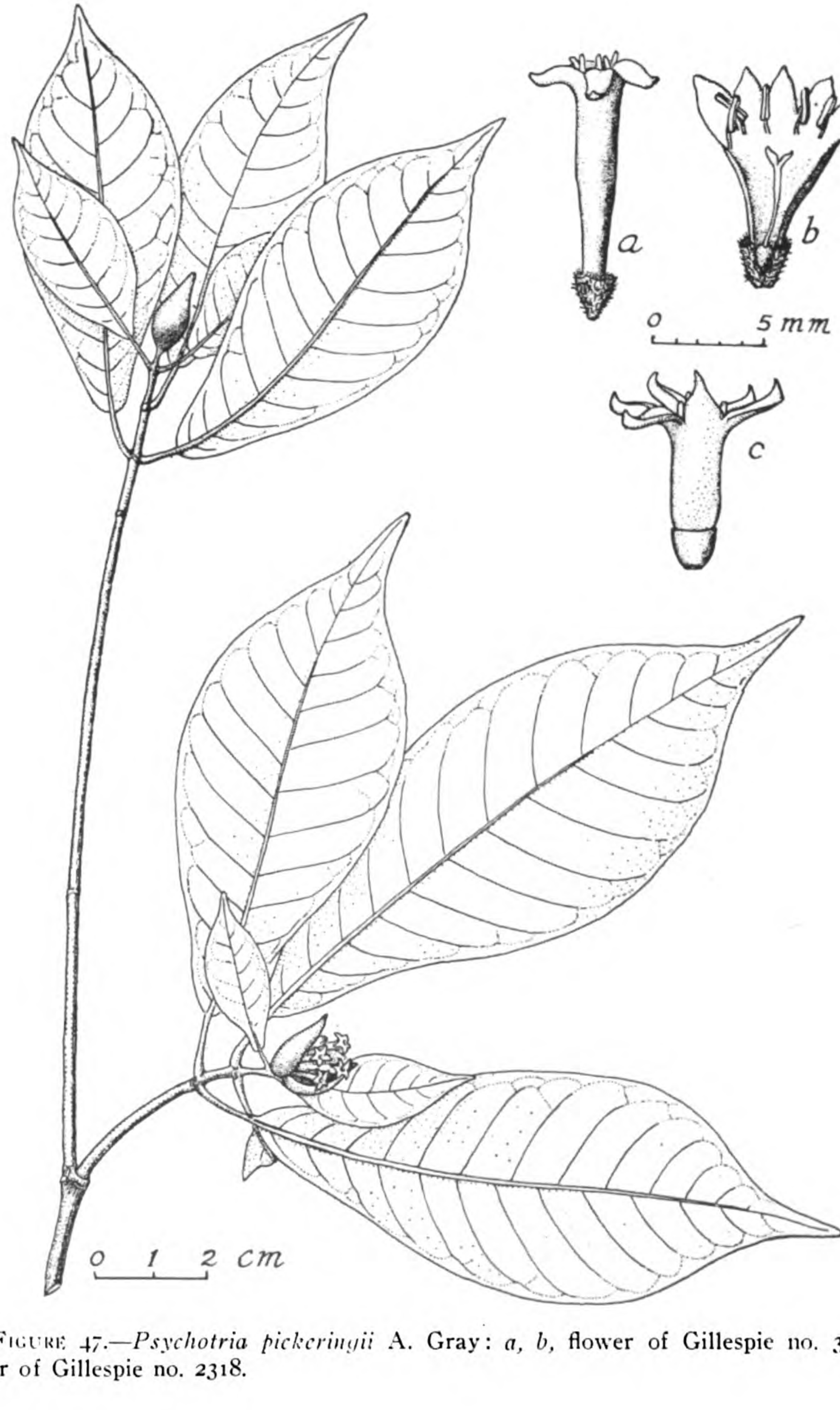

FIGURE 47.—*Psychotria pickeringii* A. Gray: *a, b,* flower of Gillespie no. 3046; *c.* flower of Gillespie no. 2318.

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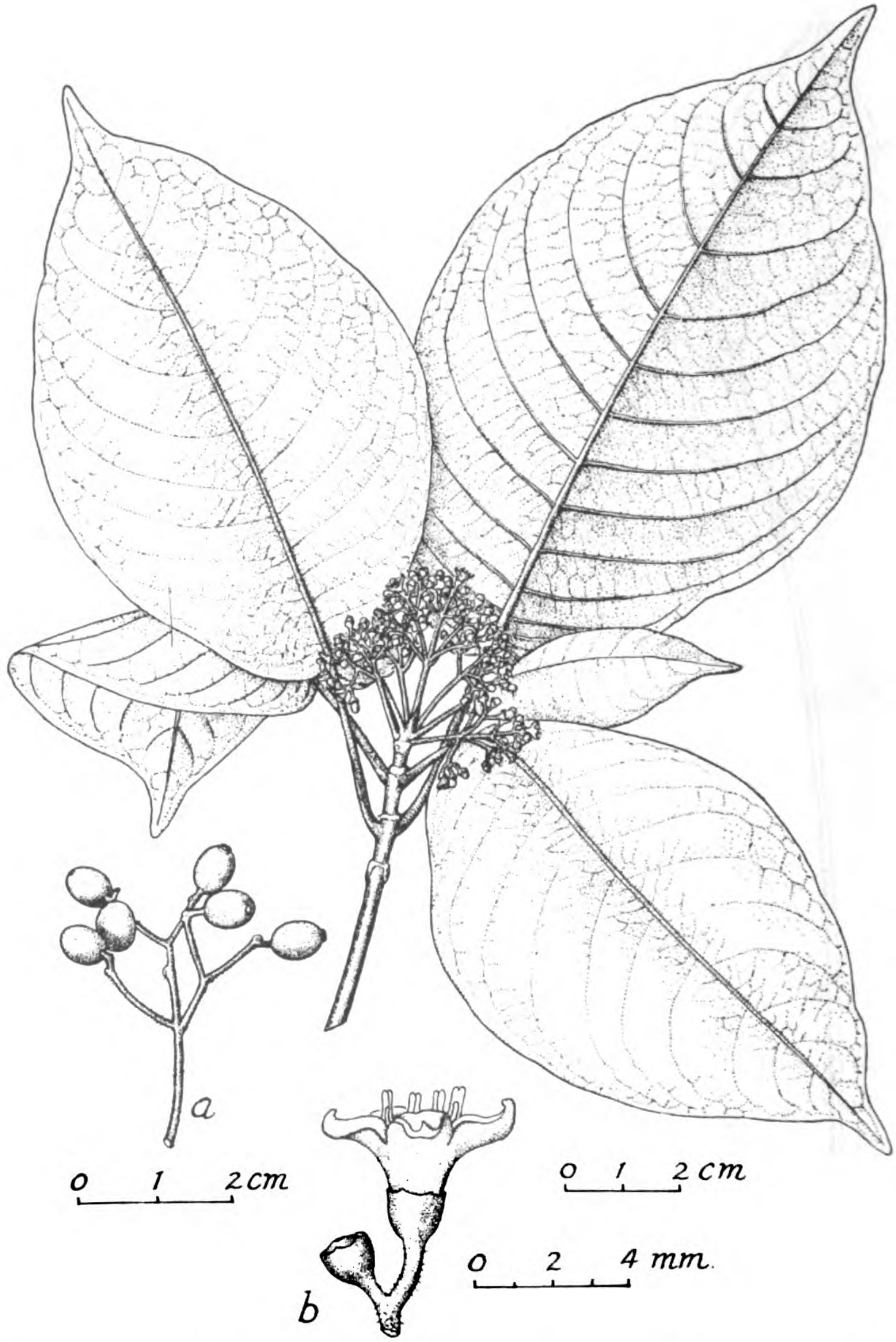

FIGURE 48.—*Psychotria taviunensis* Gillespie: *a*, portion of infructescence; *b*, flower.

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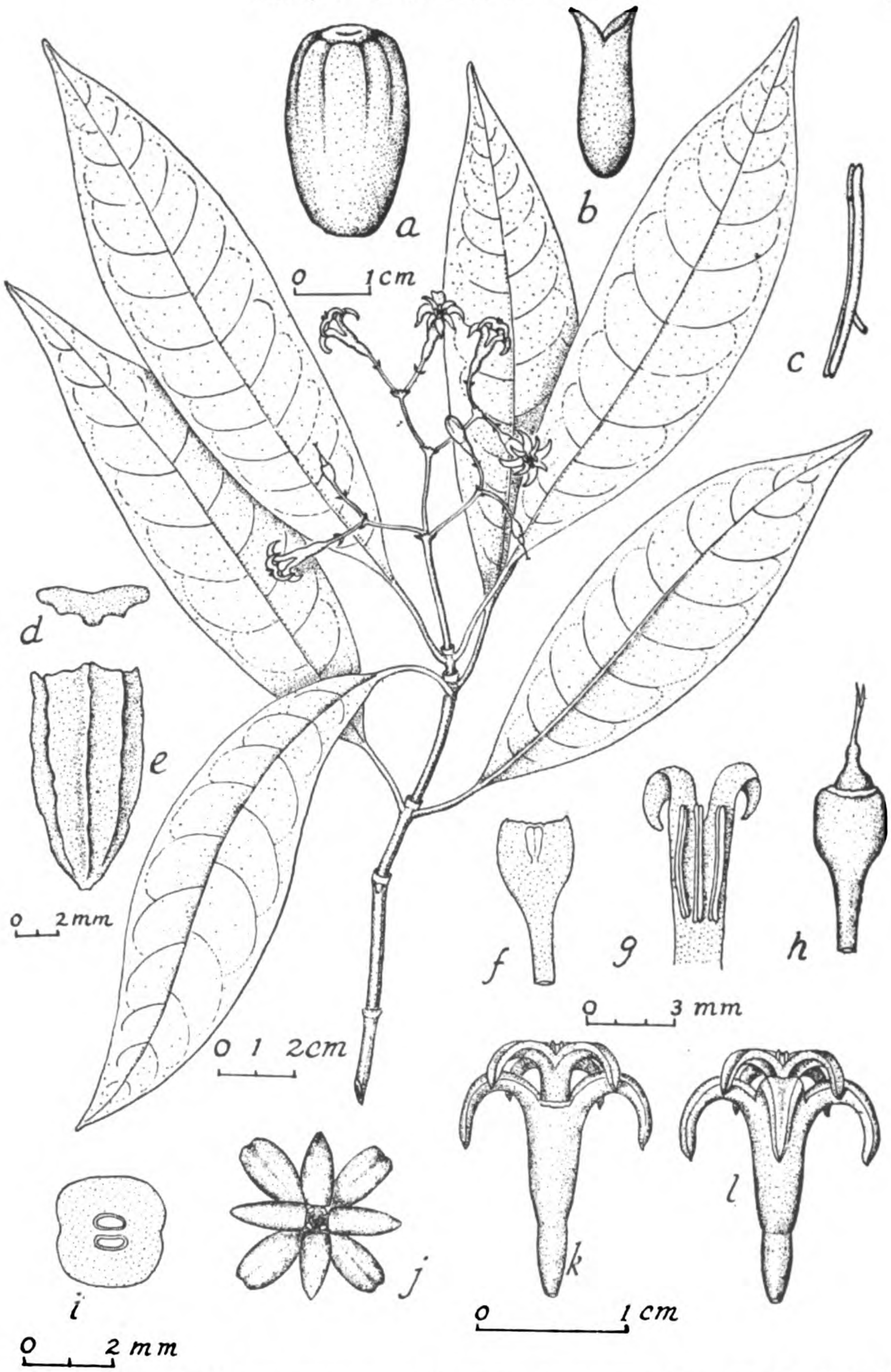

FIGURE 49.—*Readea membranacea* Gillespie: *a*, fruit; *b*, embryo, much enlarged; *c*, stamen, much enlarged; *d*, cross section of seed; *e*, seed; *f*, longitudinal section of ovary, showing one ovule; *g*, portion of corolla; *h*, flower with perianth removed; *i*, cross section of ovary; *j*, top view of flower; *k*, flower with calyx lobe removed; *l*, flower.

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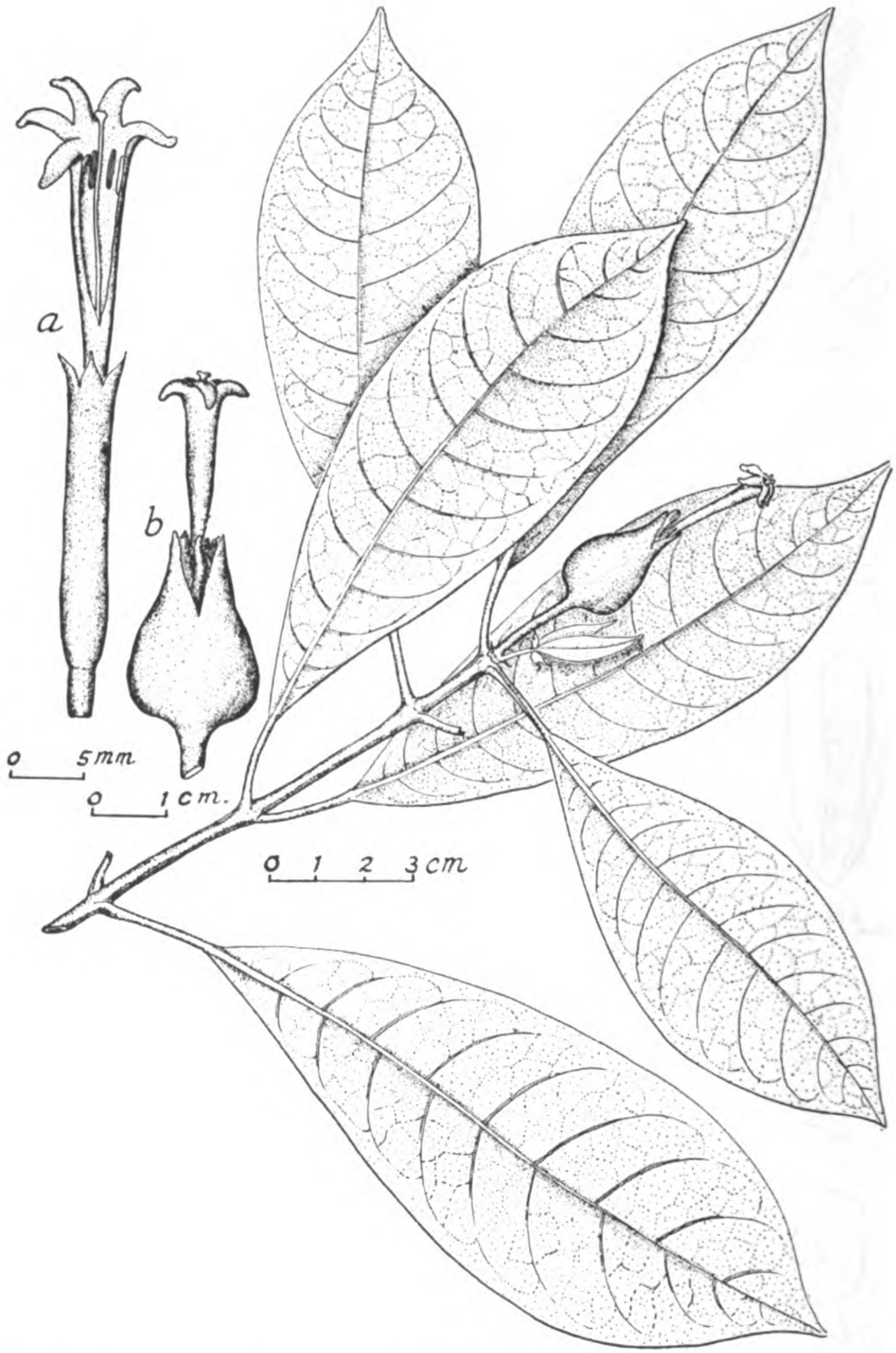

FIGURE 50.—*Uragoga lageniformis* Gillespie: *a*, flower with corolla opened; *b*, inflorescence.

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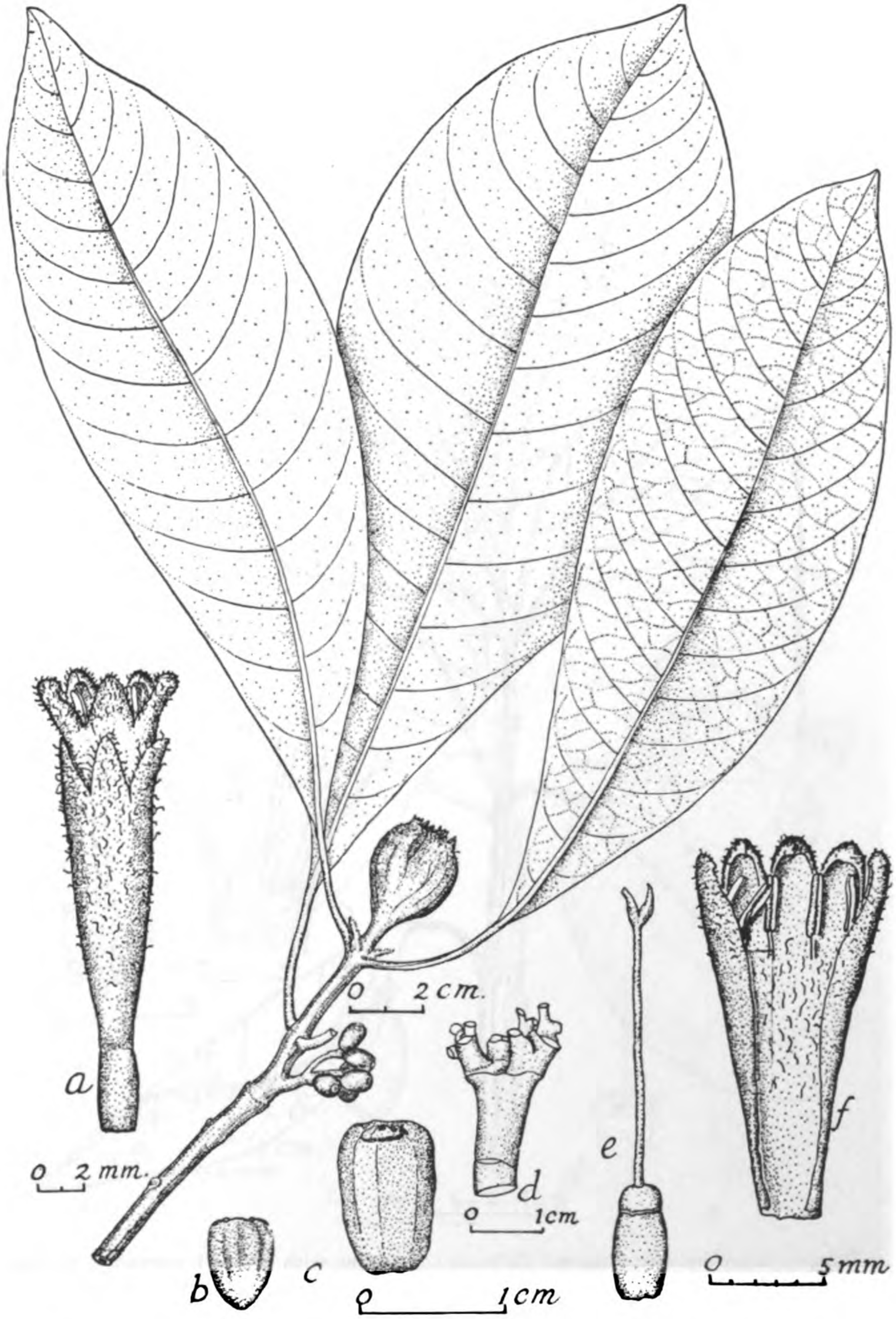

FIGURE 51.—*Uragoga petiolata* (A. Gray) Gillespie: *a*, flower; *b*, seed; *c*, fruit; *d*, peduncle with fruits removed; *e*, flower with perianth removed; *f*, corolla, opened.

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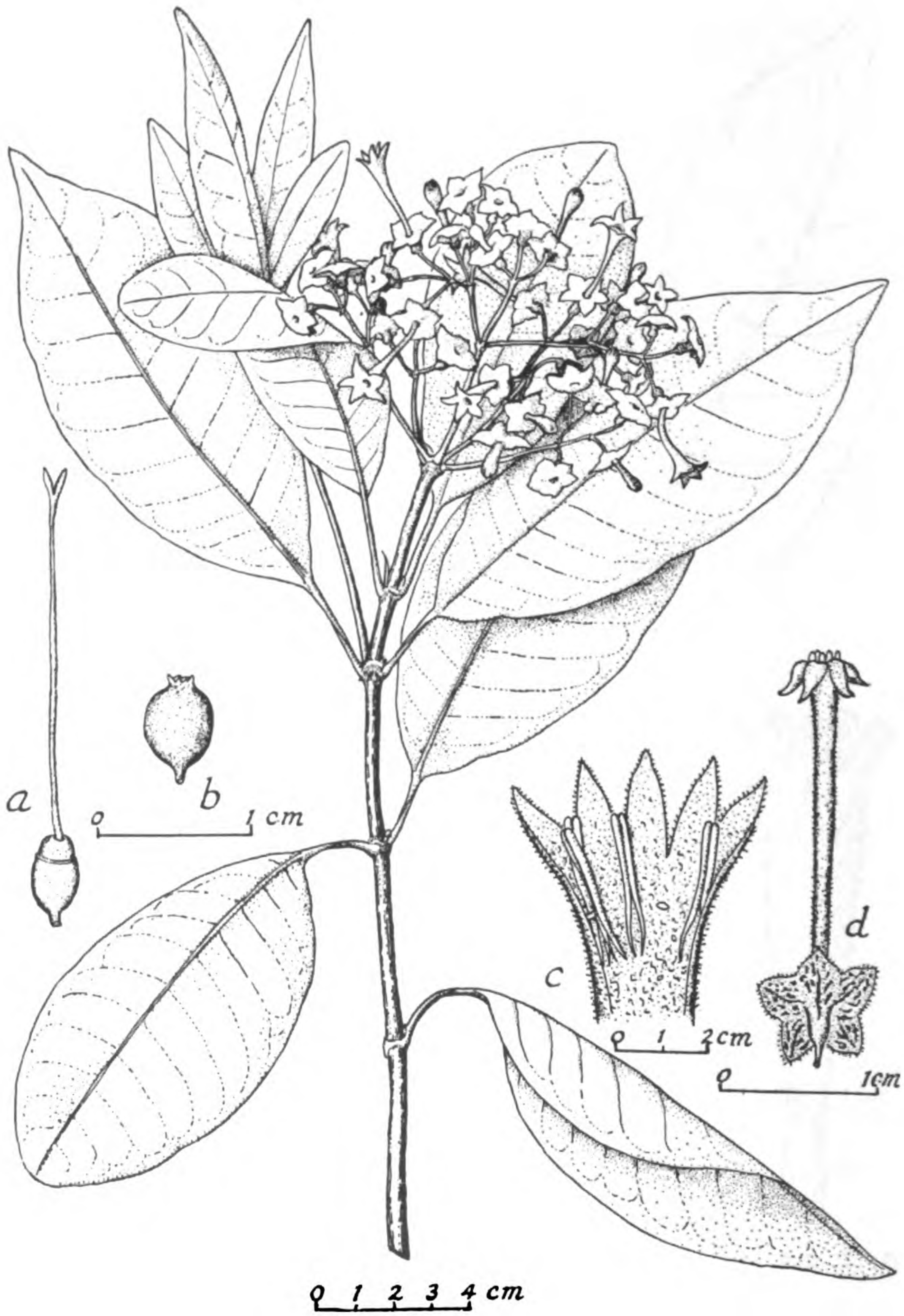

FIGURE 52.—*Calycosia fragrans* Gillespie: *a*, flower with perianth removed; *b*, fruit; *c*, portion of corolla; *d*, flower.

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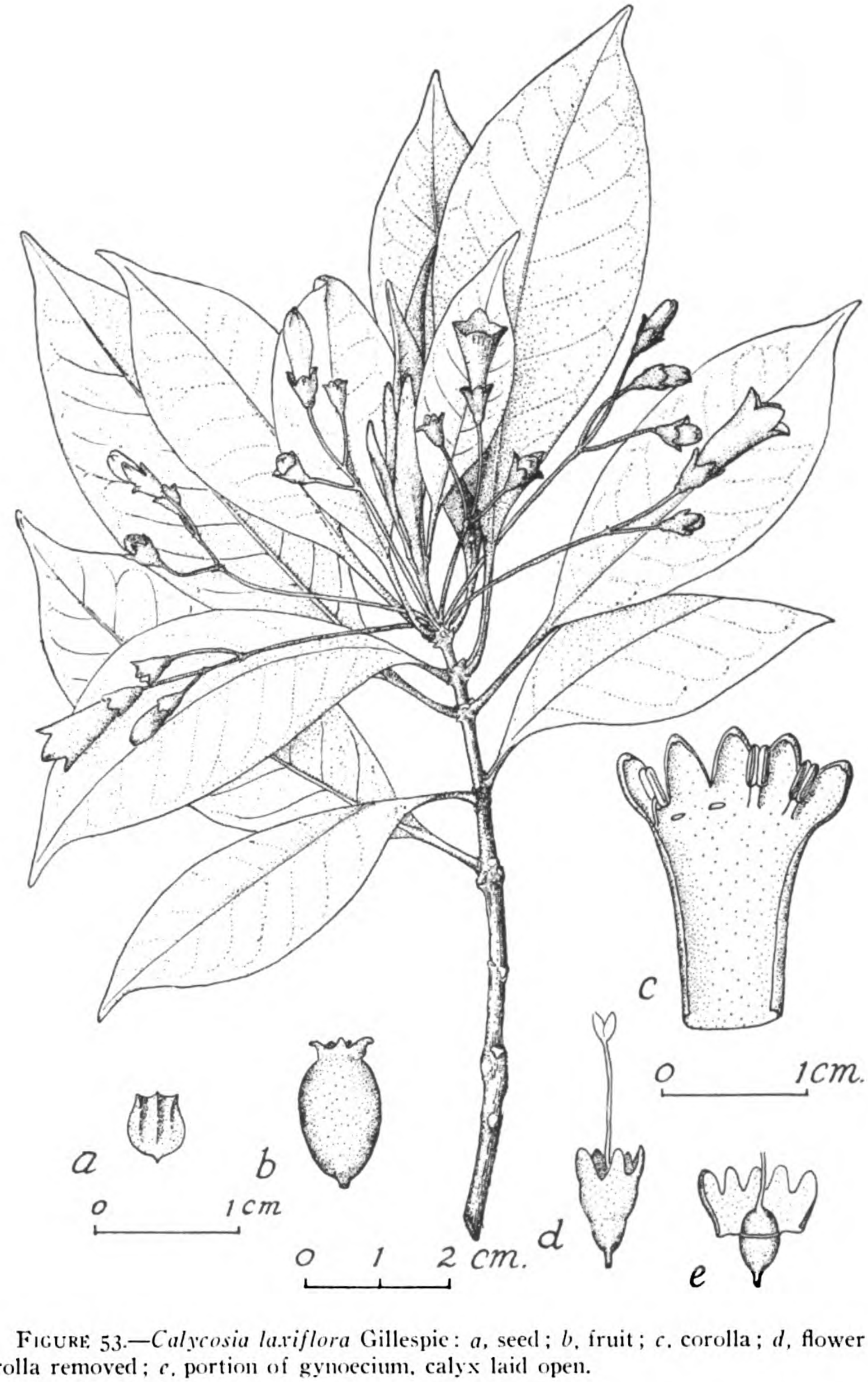

FIGURE 53.—*Calycosia laxiflora* Gillespie: *a*, seed; *b*, fruit; *c*, corolla; *d*, flower with corolla removed; *e*, portion of gynoecium, calyx laid open.

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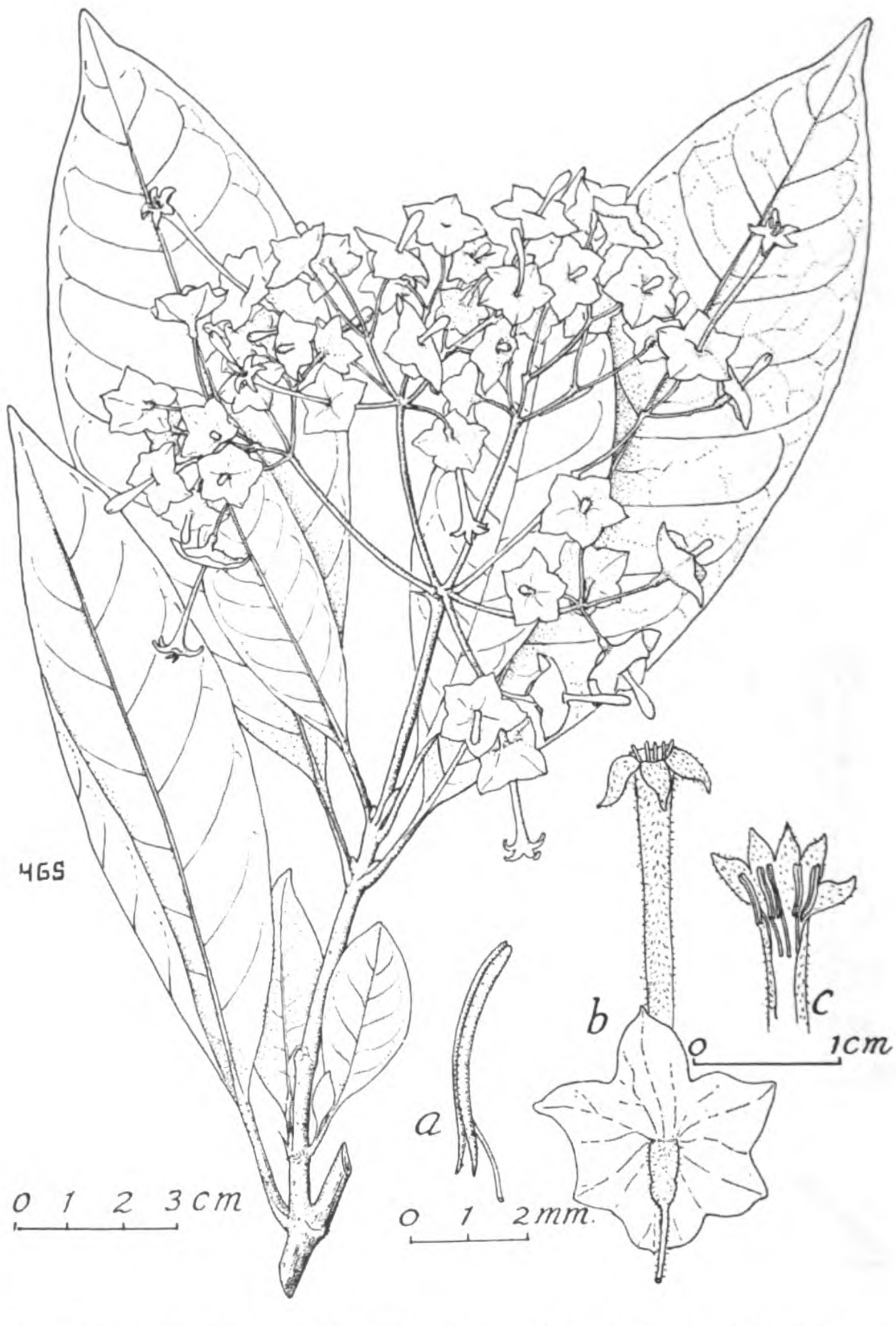

FIGURE 54.—*Calycosia magnifica* Gillespie: *a*, anther; *b*, flower; *c*, corolla opened at the throat.

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FIGURE 55.—*Calycosia monticola* Gillespie: *a*, fruit; *b*, flower with corolla removed, calyx opened; *c*, corolla opened.

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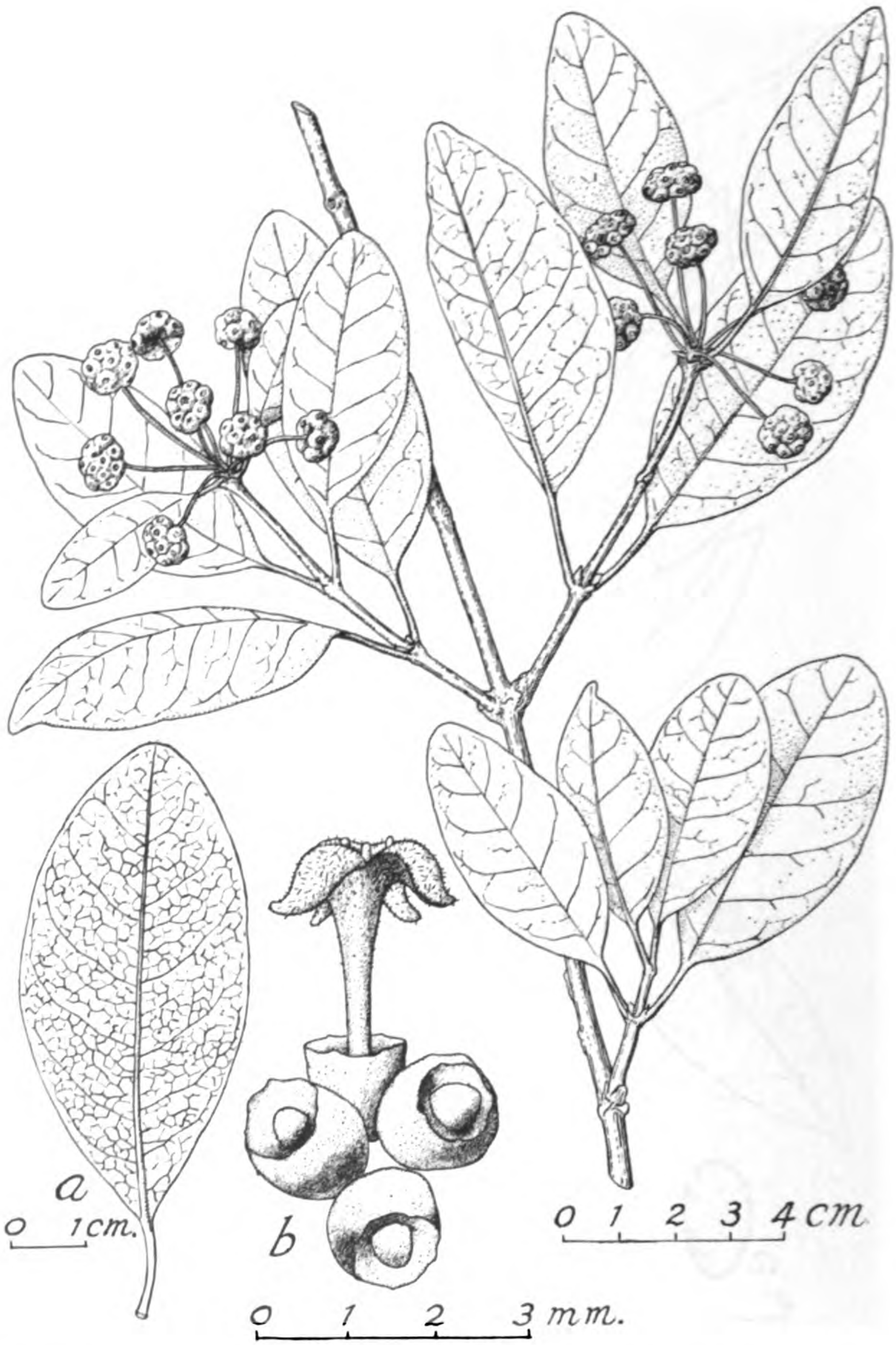

FIGURE 56.—*Morinda bucidifolia* A. Gray: *a*, leaf showing venation; *b*, portion of flowering head.

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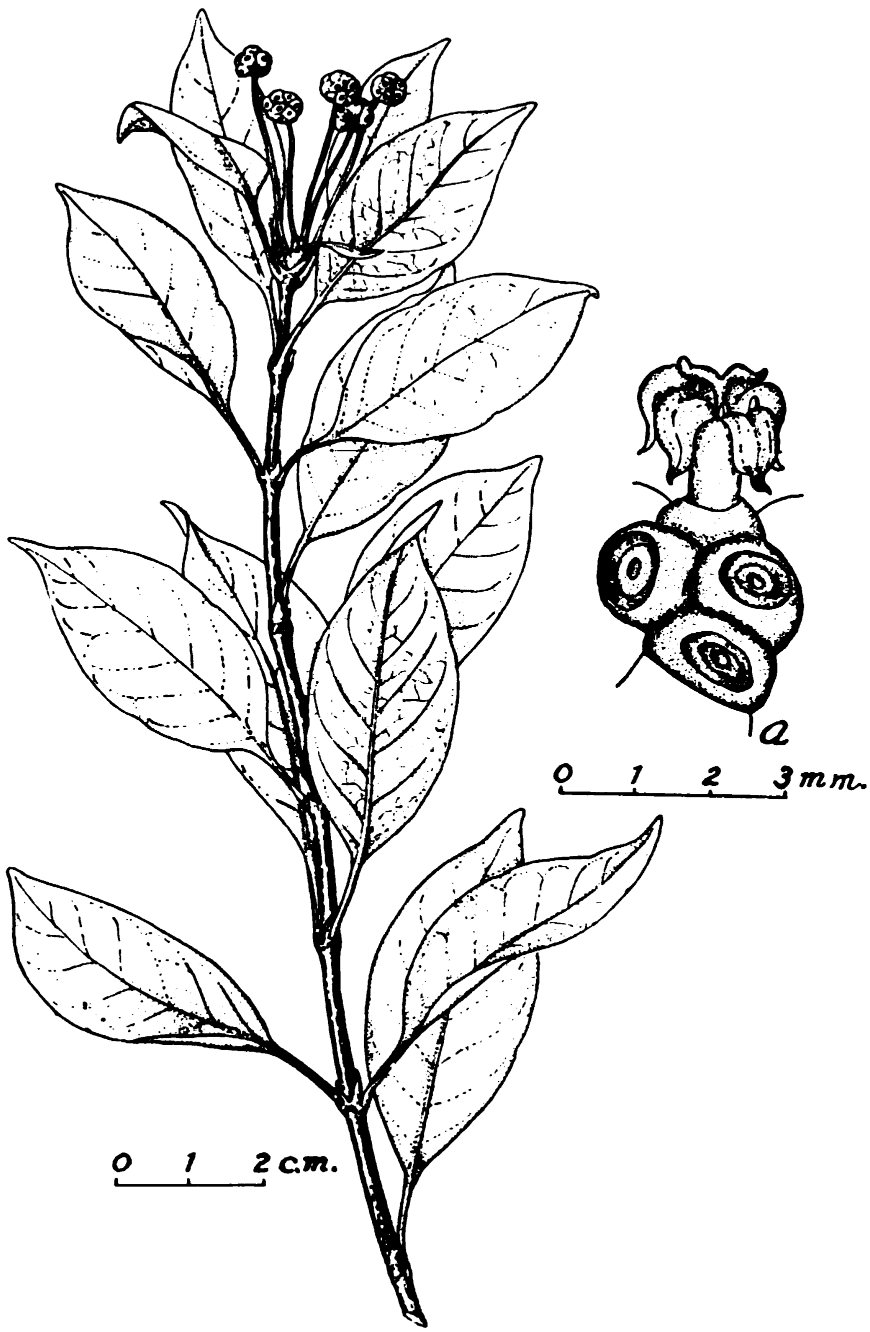

FIGURE 57.—*Morinda nandarivatensis* Gillespie: *a*, portion of syncarp with flower.

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